

Innovative Industrialised Buildings: Performance, Perceptions, and Barriers to Financing associated with Building Manufacturing

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Abstract

Most buildings are still constructed one brick or timber at a time, over lengthy periods on-site, much like ancient civilisations. This paper poses the question of whether the manufacture of buildings using digital and production line techniques from advanced manufacture can transform building to be less wasteful, quicker, more affordable, and more sustainable. This is an important question as the innovative industrialisation of buildings presents a significant opportunity for the building and construction sectors worldwide. Findings suggest that between 2011 and 2012 the economic output from the industrialised manufacture of buildings globally increased by a staggering 50% to just over US\$90 billion, with nearly half of this manufactured in the Asia-Pacific region. The paper points out that there is great potential for the manufacture of buildings to be harnessed to significantly strengthen both the building and manufacturing sectors. The research suggests that domestic building industries around the world will face strong international competition in the near future, especially as the quality of imported prefabricated and manufactured building offerings is increasing and the price is decreasing. However the transition to manufactured buildings must be undertaken in such a way as to harness a nations existing pool of skills and trades so as to allow workforce transitioning in a manner that strengthens industry. The paper highlights a number of challenges to upscaling building manufacture related to finance, insurance, and warranty structures, and presents potential options for overcoming such barriers. This paper presents findings of research undertaken as part of a Sustainable Built Environment National Research Centre (SBEnc) in Australia in collaboration with the Cooperative Research Centre (CRC) for Low Carbon Living

Keywords: Manufactured Buildings, Innovation,

1. Introduction

There are numerous economic, social, and environmental benefits associated with building manufacture or offsite construction. This presents a lucrative opportunity for the construction and advanced manufacturing industries. According to research by the Australian Sustainable Built Environment National Research Centre (SBEnc, 2014), new approaches to design, materials, and expanding the use of modular techniques can take advantage of faster fabrication times, lower costs, less waste, high quality standards, and shorter onsite construction periods. According to the research benefits of shifting to an offsite construction and fabrication model include:

- *Reduced Costs*: Faster construction times together with reduced delays from delivery, coordination, and inclement weather lead to reductions in project cost, including: cost of finance, insurances, hire equipment, plant and equipment fuel, and staffing costs, also reducing homebuyers need to pay rent.
- *Increased Safety*: Significantly improved workplace occupational health and safety by bringing the majority of building construction indoors and providing 24 hour lighting and climate control. Easy use of platforms, mini-cranes, wheeled scaffolds, and harnesses.
- *Materials Benefits*: A central facility allows for 24 hour receipt of bulk orders with secure storage which will reduce costs and delays. Materials can easily be reused which can reduce waste by 30-40%, reducing wasted materials and dumping costs - some 40% of landfill in Australia is derived from construction waste.
- *Access to Services*: A central facility allows for line-side services such as scaffolding hire, materials stores, tool shops, building component manufacture (such as window frames), and access to fixed cutting and fabricating equipment (rather than on-site handheld equipment).

In Australia, the construction of buildings offsite for onsite assembly dates back to the first set of portable iron clad homes constructed in the UK and shipped to Melbourne in the 1850's. Decades later the aftermath of World War II created conditions of abundant building materials and an urgent need for rapid rebuilding, leading a number of countries to turn to prefabrication of buildings. The first housing manufacturing plant was created in the United States in 1926, followed by the UK, and Japan in 1955.

However despite such benefits and the early uptake of building manufacturing processes the current level of offsite construction and prefabrication of buildings in Australia is low, representing some 3 percent of the value created by the Australian construction industry. This low level of uptake not only forgoes associated benefits but also opens up business to the threat of imports from the region, with Australian imports of buildings anticipated to reach a value of \$30 billion by 2025, displacing around 75,000 jobs nationally. In 2012 the economic output from the manufacture of buildings globally was estimated at just over US\$90 billion, up from \$60 billion in 2011. In 2014 the largest regional market was Asia-Pacific valued at US\$44.4 billion, followed by Europe at US\$31.5 billion, and North America at US\$10.2 billion (Research and Markets, 2014). The growing number of case studies and examples of manufacturing buildings provides

quantifiable data that can inform efforts to capture the opportunities by providing strong evidence to developers, investors, and homebuyers.

However the transition to manufactured buildings must be undertaken in such a way as to harness the existing pool of skills and trades so as to allow workforce transitioning in a manner that strengthens industry. Further a number of challenges will need to be faced such as issues related to finance, insurance, and warranty structures. For instance, until recently the Queensland Home Warranty Scheme that protects consumers and builders excluded ‘*offsite prefabrication in a factory of the whole of a building*’ (BSA, 2011). There are a number of barriers to finance that need to be overcome, namely:

- *Progress Payments*: In order to provide the access to capital needed to significantly upscale building manufacture, and capture the associated benefits, long standing financing structures need to be rearranged in the building sector that are on progress payments at different stages of onsite construction rather than being able to support factory style construction prior to transportation to site of completed product for erection. Issues related to the lack of a standardised quality assessment process for offsite construction along with gaps in current building standards and codes complicate matters.
- *Completion Risk*: There is also uncertainty around managing completion risk, such that the building is in the possession of the manufacturer up until delivery and may not be able to be easily completed should the manufacture halt operations (this may be affected by issues related to intellectual property of manufacturing methods hindering a shift in manufacturer if required). This also presents a risk to the builder or manufacturer as clients may not provide purchase confirmation until the building is delivered and able to be used for collateral for loans, leaving open the potential to withdraw part-way through the offsite construction or not being able to secure a loan at time of delivery.
- *Warrantees and Defect Rectification*: There is a need for a clear and accountable process for the rectification of defects, especially when sourcing building modules from overseas, along with insurance and warrantee structures that support offsite construction and onsite erection. The allocation of responsibility for defects is complicated by the nature of the offsite delivery model in that it can require multiple contractors to undertake offsite construction, module transportation, and onsite preparation and assembly, with each stage able to identify defects and warranty issues.

This paper investigates if the performance of manufactured buildings is superior to onsite construction methods, and considers ways to overcome barriers to financing in an Australian context.

2. Why does building manufacture present an opportunity?

2.1 Benefits of offsite construction

The shift to the manufacture of buildings stands to reduce a number of impacts including economic (reducing the time homebuyers rent while their home is constructed), social (significantly improving workplace occupational health and safety by bringing the majority of building construction indoors), and environmentally (through reduced materials wastage, reduced materials transportation, greater inclusion of energy and water efficient elements, and the potential for greater use of recycled materials). Research by the Australian Sustainable Built Environment National Research Centre (SBEnc, 2014) has shown that building manufacture allows for cost savings, faster delivery times, and the reduction of a number of impacts associated with on-site building construction methods, such as:

1. *Cost Savings:* The shift to prefabrication of buildings stands to deliver a range of cost savings to developers, builders, and owners. The greatest cost benefits are achievable in projects where replicable structures are used, such as apartments, housing developments, hotels, student accommodation, classrooms, prisons, and mining accommodations. Direct costs savings are achieved from the faster delivery of buildings using prefabrication methods, along with reductions in construction waste both from design and higher reuse of materials, weather damage of materials, damage caused from onsite handling in often restricted sites with multiple trades, and the elimination of vandalism and site theft during construction. The potential for such savings opens up the opportunity for the greater provision of affordable and social housing along with the provision of a higher level of quality and non-standard inclusions in residential and commercial buildings. In particular it would make 'sustainability' related inclusions that can deliver lower operating costs to occupants and owners more economically feasible at the construction stage (especially energy related inclusions). Not only is there significant potential for cost savings it is likely that due to a manufacturing approach being taken that rewards reducing variations that the initial price of the building is close to the final price, whereas onsite construction enjoys the ability to incur variations that add to the cost of the project.
2. *Faster Delivery:* The shift to the manufacture of buildings stands to significantly reduce construction times, along with reducing onsite delays often caused by waiting for materials delivery, coordinating service providers and subcontractors, and from inclement weather. Reducing construction times can lead to a range of benefits such as reducing the cost of fees on land taxes, equipment hire, fuel bills, and staff on-costs. The shift will also allow a greater volume of buildings to be delivered as not only is the construction time shorter it can be carried out at the same time as site preparation (i.e. footings, retaining walls, and landscaping). This is important as the shift is likely to reduce the labour requirement of individual buildings so it will be important to compensate with a growth in building output.
3. *Improved Work Place Conditions:* The shift to the manufacture of buildings in dedicated facilities will provide a number of improvements to workplace conditions, including:
 - Protection from weather and other hazards for both workers and materials, along with the provision of appropriate lighting levels 24 hours a day,

- Provision for use of central power tool facilities rather than the reliance on hand tools or portable power tools onsite, and
- Greater ability to provide elevated platforms, mini cranes, roped harnesses, and other safety equipment due to construction undertaken in a fixed facility with flat floors and overhead beams.

Furthermore, the shift to a centralised facility leads to a number of benefits such as greater flexibility in supplier choice as materials can be stockpiled rather than being needed on demand at multiple sites across a city or region, a regular delivery location with dedicated loading bay facilities reducing transportation costs of supplies, and the assurance that there will be someone to sign for materials at the facility.

2.2 What is needed to accelerate building manufacture in Australia?

Despite the opportunities there are a number of challenges to overcome, both real and perceived, in order to mainstream building manufacture, especially in Australia. For instance there are lingering miss-perceptions around the costs involved in building manufacture and the ability to produce high-end homes and commercial buildings. In the past, manufactured buildings have often been perceived to be only used for site huts or temporary transportable rooms or offices which are common in Australian construction sites, mines, and schools, however the latest marked offerings allow for high quality precision designed buildings to be produced. Along with such perceptions that need to be addressed, the shift to aggregating construction of buildings to dedicated facilities to be transported to site for erection presents a number of challenges to be addressed in order to progress the industry, namely:

Perceptions of Quality

- There is a need to shift perceptions of the industry and consumers around manufactured buildings being simply temporary reloadable structures to recognising them as high quality precision built buildings; this may be through independent quality verification, demonstration buildings, community education programs, and qualifying the specific benefits to consumers.

Design Processes and Controls

- There is a need to ensure that design, construction, and erection processes harness the full potential of the building manufacturing model and allow a streamlined delivery. This may include the updating of design codes and standards and associated changes to education and skills development programs. Key Ares for consideration include ensuring interoperability of standardised components and avoid re-invention of design practices by competing companies which may hinder the overall industry.
- There is a need to re-evaluate building project management processes related to materials and goods and services supply models to capture benefits from constructing multiple buildings in one location concurrently, such as being able to stockpile building materials and cluster buildings for sub-contractors to work on multiple buildings on one site.

- There is a need to standardise building transportation requirements and restrictions at a national level to allow for greater ease in interstate transportation of manufactured buildings or components.

Supply Chains

- There is a need to effectively engage with small businesses involved in building construction to shift from individual building contracts on various sites to a clustering of skills to deliver multiple building projects from a centralised factory-style facility. There is a need to also engage with advanced manufacturing business to assist in a transition from sectors such as the auto industry to supporting the building manufacture industry.
- There is a need to develop efficient and effective building transportation and erection processes and equipment to minimise associated costs and maximise accessibility to various site conditions. This will involve the building industry working with trucking and crane companies to a much greater extent.

Financial Models

- There is a need to address impacts on completion risks such that the building is in the possession of the manufacturer up until delivery and may not be able to be easily completed should the manufacture halt operations, or the client may not qualify for finance or withdraw part way through the construction process.
- There is a need to overcome in collaboration with banks and financial institutions the resistance to rearrange long standing financing structures that are based on progress payments at different stages of onsite construction to support factory style construction prior to transportation to site of completed product for erection.

Defects and Insurances

- There is a need for a clear and accountable process for the rectification of defects, especially when sourcing building modules from overseas. Further there are issues of the allocation of responsibility for defects given that the buildings can be constructed, transported, and erected using different contractors.
- There is a need for insurance and warrantee structures to support offsite construction and onsite erection.

Skills Development and Transitioning

- There is a need to provide capacity building to trades to adapt to building prefabrication, this may involve both the development of training courses and programs along with incentive schemes to encourage up-skilling.

3. Perceptions of Manufactured Buildings

3.1 What is the perception of manufactured buildings?

PrefabAUS Chief Executive Officer Warren McGregor believes the single biggest challenge for embracing manufactured buildings within Australia “*will be the change in mindset involved*”, with this change needing to be “*widespread; including clients, contractors, architects and consultants, project managers and suppliers*”. The lack of appreciation of the quality now possibly from manufactured buildings stems from the poor reputation of post-World War II social housing projects both in Australia and internationally. The pressing requirement for rapid rebuilding after the war years created an environment in which factory built structures came to the fore as they provided a low cost means to provide a high number of residential properties in a short time frame. While generations may have passed since then, a lack of knowledge has caused poor market perception of manufactured buildings to remain within Australia.

This negative bias has been increased through the association of prefabricated buildings with mobile and trailer homes, low socio-economic housing projects, temporary institutional buildings such as demountable classrooms and worksite offices. In a study by Steinhardt, Manley and Miller (2013) an Australian industry representative reflected that prefabricated buildings within Australia have on the whole been “*pretty cheap, nasty, flimsy, lightweight constructions*”. Such associations have resulted in misconceptions about the quality and durability of manufactured buildings and has led to prefabricated buildings being seen as inferior products to traditional on-site constructed buildings, which is not in-fact the case. It is common for consumers to think of prefabricated buildings as standard sized shipping container like volumetric boxes. But prefabricated buildings have come a long way since those transported from London to Sydney in the early 1800s. Building manufacture now encompasses a wide range of off-site fabrication of components (for example frames and wall panels), subassemblies and volumetric modules that can be used across a broad spectrum of projects including residential homes, commercial buildings, hotels, apartments, offices, educational facilities, hospitals and worksite accommodation.



Figure 1: Adara Apartments, Western Australia (compliments of Housing WA)

3.2 How can the perception be changed

It is important for prefabricated buildings to use innovative design and new technology to be able to disassociate with traditional box-like features and change the current market perception. One such example, The Adara Apartments in Western Australia has achieved this (as shown in Figure 1). Designed by Campion Design Group and built by Hickory over a 12 month period, this building is a success story for the prefabricated building industry. Once the initial foundations and amenities were laid, 96 prefabricated modular components were brought and installed over a 10 day period. This structure boasts a reduction of 10- 12% less in construction costs, 35- 40% less aggregate funding costs and improved return on equity for investors. Despite new prefabricated buildings rising in cities around the world, the slow growth of prefabricated residential buildings is due in large to the reluctance of consumers to move away from traditional on-site building methods. In a US study into consumer perceptions of residential building methodologies in 2007, on-site built homes were more favourable than prefabricated homes, rating highest with ‘*respect to quality of construction, resale value, availability of financing, quality of surrounding neighbourhood and the look and feel of the home*’ (HUD, 2007). Of these considerations, the perceived quality of construction was the most influential concern that consumers had when selecting building methodology. Additionally, consumers largely select traditional building methods as they provide for a sense of reliability and security. However manufactured products like ‘The Auburn’ in Australia shown in Figure 2 are changing the perception of the level of quality available.



Figure 2: The Auburn (compliments of Allsteel Homes, Australia)

Shifting negative perceptions of manufactured buildings from temporary, low quality structures to high quality precision designed buildings is critical to increasing market share. However the marketing of prefabricated building needs to be carefully considered as despite being clearly more affordable and able to be delivered in much shorter timeframes using terms like ‘low-cost’ and ‘fast’ may resonate with perceptions of low quality. Terminology surrounding manufactured buildings can also impact perceptions of quality. Terms such as ‘Modular’ or ‘Prefabricated’ tend to again have associations with low quality buildings from the past, with companies now not making a point of the construction method but rather the quality, timeframes, and price.

The Japanese building sector has taken a targeted approach with companies such as Sekisui House, Sekisui Heim, Misawa Homes, and Daiwa House targeting upper socio-economic and environmentally conscious clients. These prefabricated models available are continuously analysed and improved with qualities such as thermal efficiency and energy consumption as well

as seismic and acoustic performance. This strategy generally means a higher upfront capital cost do to the improvements but builds the reputation that efforts are being constantly made to reduce operating costs over the lifespan of the building, such as from energy and water consumption.

4. Overcoming Barriers to Financing Building Manufacture

4.1 Construction phase financing

The most often mentioned barrier to financing building manufacture is that as the construction phase takes place in a private facility, rather than onsite, it is difficult to use financing mechanisms that have been established to support onsite construction. Further as the value of the manufactured product is substantial compared with other manufactured goods a series of progress payments is preferred by builders. Hence the conflict between capturing the benefits of offsite construction and accessing progress payments using current financing arrangements presents a significant barrier to the upscaling of building manufacturing. This is due to the fact that unlike onsite construction, where the partially completed building is in the custody of the owner or developer and therefore forms collateral on the loan, using an offsite model calls for progress payments to be made while the building remains in the custody of the builder in a private facility.

Lending institutions are however accustomed to releasing funds for buildings constructed offsite after the building has been placed on site. The stage at which funds are released varies between lenders from when the building is installed on approved footings to when a certificate of occupancy has been issued. Hence the issue of progress payments is currently being overcome by developers, or even the building manufacturers, providing the funding required for the construction phase to then allow customers to seek purchasing finance based on the completed building. Although this model allows for the client or owner to secure traditional loan products based on a completed building there are two draw backs that are hindering the growth of the industry. Firstly it lends itself to large companies who can afford to provide construction phase financing, with smaller operators having to mortgage their own assets (or requiring customers that have appropriate assets to leverage), and secondly it means that the risk is carried by the builder or manufacturer until payment is made. Since the purchase finance cannot be secured prior to the construction stage this leaves the builder open to risks like the customer not being able to secure funding after the building is complete, or having the client change their mind before the building is completed.

4.2 Providing assurance of quality

A key element in ensuring the quality of buildings constructed offsite using prefabrication and/or manufacturing based processes is the provision of associated design codes and standards that can be assessed for compliance. In the USA, the U.S. Department of Housing and Urban Development can created a construction and safety standard for offsite construction and building manufacture, the '*Manufactured Home Construction and Safety Standards*'. This standard classifies a manufacture home as one that is '*constructed on a permanent chassis*' and provides standards for design, construction, and installation of manufactured homes to assure the quality, durability,

safety, and affordability. The standards include a dispute resolution component along with the provision for inspections and record keeping.

A second key way to provide assurance of quality is through the provision of a warranty or assurance scheme. For example in Japan, where prefabricated housing represents some 13 percent of the building stock, building owners are provided with a standard 20 year warranty which entails strong after sales service. In the UK efforts to increase the viability of securing construction financing have focused on providing independent certification of the processes used in offsite construction and building manufacture in collaboration with the Council of Mortgage Lenders. The '*Build Offsite Property Assurance Scheme*' (BOPAS) seeks to provide assurance to lending institutions that buildings constructed offsite are sufficiently energy efficient and durable and will be readily saleable for a minimum of 60 years. The BOPAS certification process consists of two components:

- (1) A *durability and maintenance assessment* that provides an independent technical assessment of the building's suitability and encompasses issues relating to reparability, maintainability, and suitability for housing (or other building types).
- (2) Accreditation of *the design and/or construction processes* that is solely risk based, in which designers, manufactures and constructors are evaluated on key performance areas at each stage of project development from concept design to project completion. The major performance areas are: risk management, competency management, configuration management, procurement management, and process control.

The process accreditation occurs in two stages. An organisation initially undergoes a gap audit in which any significant weaknesses are highlighted and adoption of best practice is facilitated. A full implementation audit is then undertaken in which key performance areas are examined against a best practice standard, with accredited organisations undergoing regular visits to ensure proficiency is maintained. A key feature of the BOPAS system is the use of an online database that provides valuers, lenders and surveyors a single point of reference to find all accredited designers, manufacturers, constructors and building systems.

4.3 Provision of loan insurance

In the USA, the provision of government-insured mortgage loans offered by the Federal Housing Administration encourage mortgage lenders to finance manufactured homes by protecting the lender against the risk of default from the buyer. Traditionally, manufactured homes have been financed as personal property through comparatively high-interest, short-term consumer instalment loans. Mortgage lenders have now established appropriate products that allows buyers to finance their home purchase at a longer term and lower interest rate than with conventional loans. The buyer pays an upfront insurance premium, along with an annual premium based on the declining balance of the loan. The maximum loan term is 20 years for a manufactured housing loan. Despite such progress a study has found that from 2001 to 2010 in the United States an estimated 65% of manufactured housing customers who owned their land and took out a loan financed their purchase with a chattel loan, which is a secured loan where the financier takes

charge over the asset. Although chattel loans have lower initial costs and may close sooner than mortgages, interest rates on chattel loans, however, are usually higher and chattel loans generally have lesser consumer protections than mortgages. Overall, customers buying prefabricated homes tend to pay higher interest rates for their loans than ordinary home buyers. In 2012, according to the Consumer Financial Protection Bureau (CFPB, 2014) approximately 68% of all manufactured-housing purchase loans in the USA were classified as high-priced mortgage loans.

4.4 Issues related to defects and contractual arrangements

Further to issues related progress payments there are issues related to the responsibility for defects given that the construction of the building is now undertaken in two stages that may involve different contractors. The first stage is the offsite construction stage to produce building components or modules, and the second stage is related to onsite construction, such as site preparation, construction of footings and building core, and transportation, lifting, and assembly of building modules. At each of these stages defects can be present and the responsibility for defect identification and rectification is not always clear cut which can lead to conflict between parties. Litigation can arise between the manufacturer and the installer in cases where the contractual responsibility has been divided between the two, where both parties are likely to point the finger at one another over delays and defects.

The potential for such issues can also be of concern for lending instructions, causing a barrier to finance, however this can be overcome through a 'Design and Construct' contractual arrangement. In such an arrangement the builder or developer will undertake the design and enter into a subcontract with a manufacturer who will produce the modules. The builder will undertake associated on-site construction and installation of the modules. Within such a contractual arrangement, there is a single point of responsibility whereby the builder is accountable for all design, construction and manufacturing faults and defects. The manufacturer of the modules or building components is responsible for rectification of defaults as if it were any other subcontractor.

5. Conclusions

The manufacture of buildings has the potential to provide high quality and cost-effective houses, apartments, office blocks and a range of other building types, utilising the technologies, materials, design knowhow, and construction experience currently in the both the building and manufacturing sectors. This together with the benefits pointed out previously suggest that it is likely that a large part of building construction will shift from individual buildings constructed onsite to the aggregation of construction in dedicated facilities to be transported for erection on site. Manufactured buildings are unlikely completely replace conventional building approaches, but they stand to significantly increase share in the market, particularly for multi-storey buildings. As with a number of other advanced industries, such as renewable energy technology, the slow recognition of the value that can be created through the manufacture of buildings in many countries such as Australia may lead to a missed opportunity with off-shore providers dominating the nation's future building market.

In order to capture the potential of building manufacture the building sector needs to quickly develop the infrastructure for the construction of buildings in centralised facilities and their transport and erection on site. This may involve a transition strategy that includes an initial push for the use of panelised onsite construction to build momentum in the manufacture and erection of prefabricated components and modules. It is particularly important to develop the sector in a manner that takes advantage of the cost effectiveness of sourcing building modules off-shore, otherwise such offerings will compete with domestic construction. There are already cases of off-shore building manufacturing plants that are importing Australian electrical and plumbing components to ensure that standards and codes are met when shipping to Australian customers. Hence, if countries like Australia do not seize the opportunity of building manufacturing, foreign companies will certainly continue to bring them to market, which if not harnessed as part of the sectors overall development could lead to job losses across the building sector and its supply chain.

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