Centre for
Integrated Project Solutions

Efficient construction: Analysis of integrated supply chains for innovative offsite housing manufacturing

RMIT UNIVERSITY

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Industry partners

The project is supported by industry partners Frasers Property, Metricon Homes Pty Ltd, FMG Engineering, the Master Builders Association of Victoria.

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In response to more than a decade long lag in innovation and efficiency in the Australian housing sector, RMIT University's Centre for Integrated Project Solutions, in collaboration with industry partners, is undertaking research into best-practice offsite manufacturing with the research project 'Efficient construction: Analysis of integrated supply chains for innovative offsite housing manufacturing'.

This half-million dollar, Australian Research Council (ARC) Linkage Project brings together researchers and industry partners to analyse large-scale collaborative efforts required for innovative offsite manufacturing in the Australian housing sector, and to learn from best practice.

Industry involvement is significant throughout every stage of this project. A project steering committee comprising RMIT researchers and industry members meets regularly to ensure objectives align with industry priorities and are positioned to achieve industry outcomes.

Background

The Australian housing sector has struggled to meet demand for more than a decade, with construction methods remaining unchanged and unimproved. Reports show that average construction times have increased by 40% in the last 15 years.[1]

The industry is still considered by many to be a cottage industry taking very little advantage of modern construction techniques and characterised by low productivity, lack of innovation and inefficiencies. Many problems are linked to fragmentation of the supply chain.

While integration of construction supply chains has been proposed as a solution, there is little evidence that it has been adopted by practitioners. However, there is still opportunity to drive improvement in industry. One potential strategy that could increase innovation and efficiency is offsite manufacturing: the manufacture and pre-assembly of components, systems or modules before installation into their final location. This study will explore case studies of different types of recent innovative examples in the Australian housing sector.

There is a perception that offsite manufacturing is carried out by large, established construction contractors and/or large construction manufacturing companies that have invested heavily in innovative manufacturing systems for prefabrication. However, the organisation driving offsite manufacturing may, in fact, be a large developer with significant investments in capital, or a smaller builder that has found a niche in affordable modular housing. In many instances, construction sites employ a hybrid of construction techniques, blending both offsite and traditional onsite methods.

In many of these situations, collaboration may be the key to success in offsite manufacturing. With this in mind, this research will explore case studies of recent innovative examples of offsite manufacturing, with a focus on collaboration across the construction supply chain.

A working definition of offsite manufacturing

While the term *offsite manufacturing* has often been used interchangeably with *prefabrication, industrialised building* and *modular building*, for this study we use *offsite manufacturing (OSM)* as an umbrella term to refer to the manufacture and assembly of items such as building components, systems, pods and/or complete modular constructions in a controlled environment away from the construction site, ready to be transported to the site and installed.

Specifically, OSM is differentiated from other terms in the following ways:

- OSM always involves the *prefabrication* of a component, system or unit, which is then transported to a site where construction installation takes place.
- OSM may involve the manufacture of a *modular building*, but it may also accommodate the manufacture and assembly of other forms such as panels, systems or pods. A *modular building* is therefore only one type of OSM product.
- OSM typically takes place in a controlled offsite environment that makes use of highly automated manufacturing processes combined with pre-assembly. In such cases the manufacturing process can be characterised as *industrialised*.

The different types of offsite manufactured items (refer to Figure 1) vary with increasing technical complexity of design, construction and production. As complexity increases, often so too does the complexity involved in supply chain collaboration.

Figure 1. Different types of offsite manufactured items.

Building components	Windows, roof trusses, prefabricated concrete columns and beams, etc.
Building systems	Timber cassette floors, panel wall systems.
Pods	Kitchen and bathroom pods.
Modular detached units	Affordable housing, volume customised residences, disaster relief shelters, temporary construction camp dwellings, mining camp offices.
Modular housing units	Complete units stacked into low, medium or high-rise buildings.

1. Gharaie, E., Wakefield, R. & Blismas, N. (2010) 'Explaining the increase in the Australian average house completion time: Activity-based versus work-flow-based approach', Australasian Journal of Construction Economics and Building, 10 (4), 34–49.

Benefits of OSM

International studies suggest the increased use of OSM has the potential to reduce construction time by up to 80%, materials waste by up to 90% and onsite accidents by up to 80%.[2]

Other reports suggest that manufacturing offsite in controlled environments considerably improves the craftsmanship and quality of finished products, and offers numerous benefits.

Improved time performance:

- concurrent design and manufacture
- reduced impact of poor weather
- fewer construction defects and a reduction in rework.

Improved environmental and social sustainability:

- predictable performance of the homes in use
- improved sustainability of the completed homes
- reduction in waste of materials
- improved working conditions in a controlled environment
- occupational health and safety benefits
- improved handling/storage of materials

Reduced variability and reduced costs

- reduction in unit cost as production increases
- need for fewer subcontractors on site
- reduction in vehicle movements on site.[3]

Given the many benefits of OSM, it is unsurprising that Sweden, the United Kingdom, China and Japan have increasingly mobilised it as a construction approach. It stands to reason that the $43 billion Australian construction industry should be preparing for a future where more construction occurs away from the building site.

Barriers to OSM

To date, uptake of OSM in Australia has been limited. A considerable number of barriers to OSM are linked to the belief that it is a dramatic departure from traditional construction methods and that change is difficult. A commonly held misconception in industry is that OSM requires large volumes of land, manufacturing plants, equipment, research and development. These seemingly large investments become daunting in light of uncertainties surrounding market stability and/or demand in Australia, coupled with concerns about OSM products. There are doubts about whether the current pool of management and building competencies and skills can support the technical and organisational changes required by OSM. Questions have also arisen regarding whether standards are compatible with existing regulations and whether new OSM components or systems may solve some problems while creating other challenges.

Underlying all these barriers is a further significant challenge: OSM requires an extraordinary collaborative effort across the network of construction chain actors, from developers to builders to trade contractors to suppliers, in order to initiate and achieve change.

Collaboration, integrated construction supply chains and OSM

Achieving collaboration in OSM contexts is no mean feat. There is a small but growing body of case studies emerging from local and international settings suggesting that technical changes in OSM products are linked to changes in organisational and inter-organisational processes. The decision to shift to the use of OSM can alter the sequence of steps in project planning and implementation, with key processes in design, construction methodology and quality control being carried out much earlier.

Changes in process sequencing, along with other factors such as the novelty of OSM products and the need for new management and trade-specific skills, have led practitioners and researchers to note that OSM dramatically increases the need for members of the supply chain to work more closely together, dovetail their tasks more tightly, consult more extensively and share learnings in a timely way. It is becoming clear that collaboration is fundamental to the success of OSM. But what are the conditions that enable such collaborative efforts? What environment allows creative shared problem solving? What allows organisations and people to take risks? What allows previous held beliefs about insurmountable barriers to be changed?

2. Miles, J. & Whitehouse, N. (2013) 'Off site housing Review: February 2013', Construction Industry Council, report for Department for Communities and Local Government and the Department for Business, Innovation and Skills.

3. Compiled list adapted from BRE 2004, Modern Methods of Construction: BRE presents the arguments in favour of off-site production, BRE factsheet, UK.

Project objectives

In light of the benefits and barriers of OSM, and the potential to achieve improved industry efficiencies and standards through increased collaboration in OSM, the project seeks to:

- Analyse the specific Australian housing barriers and enablers to introducing innovative OSM through a series of case studies.
- Develop an integrated supply chain practice model, based on the analysis, that includes measures of collaboration mapped to productivity performance and that can be used to guide OSM effectiveness.
- Test and evaluate the collaborative practice model through expert stakeholder panel assessments and then develop virtual OSM construction simulation training and then pre- and post-testing of live projects and cross-case comparisons.

Industry and research outcomes

Project outcomes include

- Development of supply chain theory and practice through the analysis of case studies.
- Conceptual development, supported by practical examples, on innovation and collaboration for transformation within organisations and the industry.
- Collaborative practice models for housing supply chains.
- New simulation-based training programs incorporating industry-based collaboration scenarios.
- Evidence to enable informed government policymaking for housing.

Two key outcomes, a collaborative practice model (or models) and training programs, will be designed for direct impact on industry.

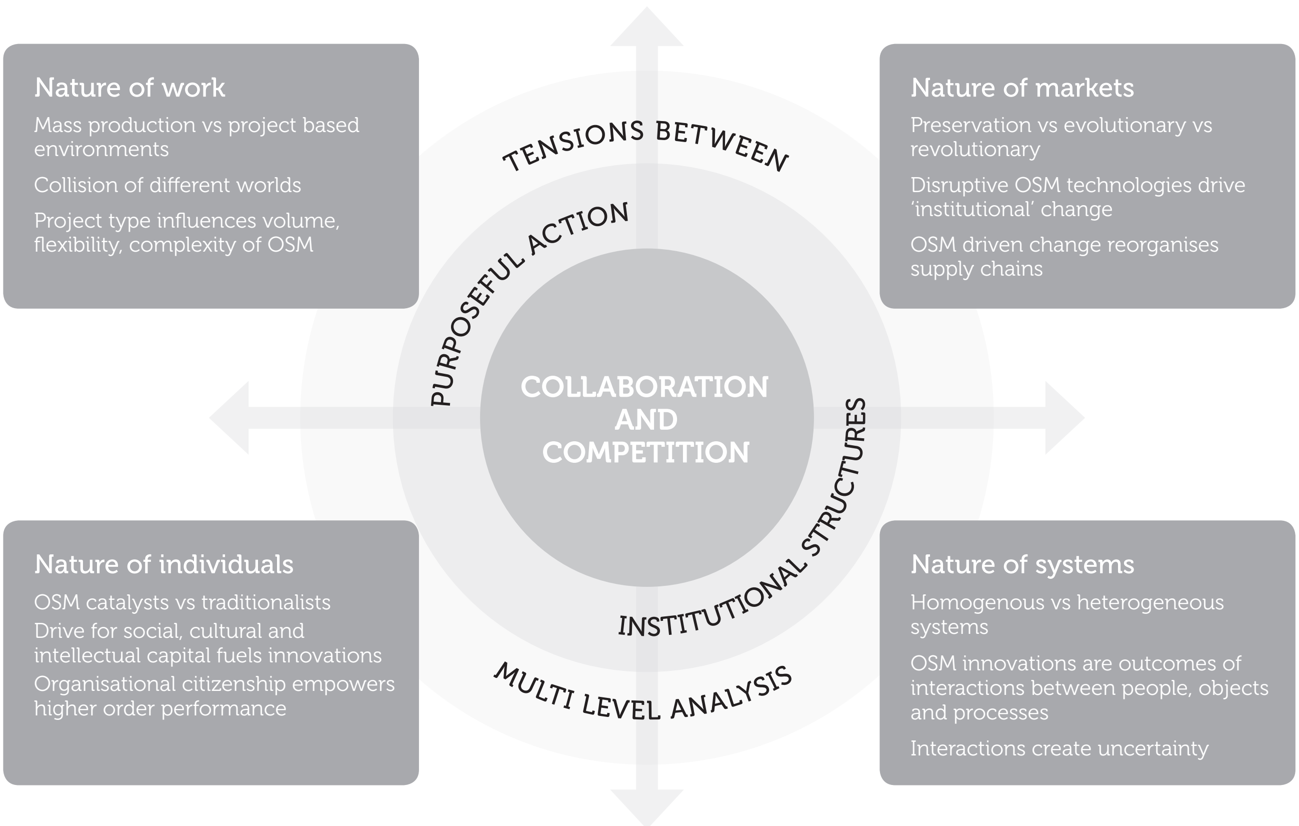
Collaborative practice models for housing supply chains

The research team has developed a conceptual framework based on four areas of collaboration that are emerging as vital to OSM success.

The framework will inform the creation of collaborative supply chain practice models for industry, and will help researchers and practitioners to understand the nature of large-scale collaborative efforts in theoretical and practical ways as a blend of underlying economic and social structure and individual behaviour.

The project will explore collaborative activity across the four areas:

- **Collaboration and the nature of work**
  Work in construction involves project-based work. It may be unpredictable and volume of production may vary. Work in construction can also have very different outputs ranging from small-scale short-term projects to large-scale complex projects that run for many years. OSM products, systems and operations may still have to be flexible and responsive to project environments. Collaboration may change from project to project and from factory to factory.
- **Collaboration and the nature of individuals**
  Construction collaboration is focused on performance i.e. time, quality, cost. However, the link between collaboration and performance measures is not simple. Collaboration is linked in complex interrelationships with new products and processes, learning, power, coordination and communication, which are difficult to capture and quantify. People invest in collaboration to build capital in various forms: social (relationships), cultural (artefacts), intellectual (knowledge) and financial (revenue opportunities). Such investment may involve trade-offs and failures and may not result in immediate success.



- **Collaboration and the nature of markets**
  Collaboration takes place not just between individuals, but also between organisations or between organisational units. Supply chains are embedded in a larger context shaped by institutional factors: economics, laws, governance, regulations, industry and societal culture. These 'institutions' create and re-create the 'rules of the game' i.e. the way things are done. The formal and informal dimensions of institutions and organisations and how these shape and are shaped by collaborative activities influences collaborative environments.
- **Collaboration and the nature of systems**
  Collaboration in construction is a mixture of technology and social processes, involving a complex network of human and non-human elements. While collaboration tends to emphasise the role of people, material elements like products, IT systems, artefacts and equipment can play a critical role in collaboration as well.

Underpinning all areas of the model is the question of whether collaboration and competition are mutually exclusive. We suggest that there are creative ways to manage the tension between the two.

Simulation-based training programs incorporating industry-based collaboration scenarios

Apart from developing collaborative practice models, the research team will also create innovative materials for new training programs focusing on strategic and operational collaboration.

Findings from the research will be used as the basis for designing collaboration-based business cases and scenarios.

These scenarios will be developed into detailed scripts by professional writers and transformed into interactive simulations involving professional actors. Simulation-based training for selected participants will be conducted at a virtual simulation training laboratory owned by the Master Builders Association of Victoria – the innovative Building Leadership Simulation Centre is the only one of its kind in the southern hemisphere.

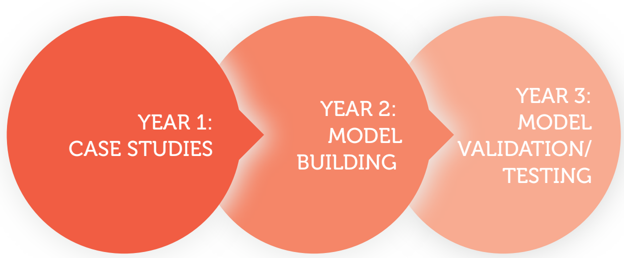
Participants in simulations will be presented with different collaborative dilemmas and challenges, then asked to respond to these. At the end of a training session, participants will be given feedback and input on their performance.

Outcomes of the training programs will also be used to refine the collaborative practice models.

Project timelines

The project began in January 2015 and will be completed by December 2017.

Using a research approach known as actor-network theory, researchers will explore key case studies, identifying and analysing the relationship between people, organisations, systems and the underlying 'rules of the game'. This exploration will provide insights into how recent successful OSM examples addressed barriers to OSM implementation and helped to achieve improved outcomes for businesses.



Year 1: Case studies

Researchers will conduct in-depth analyses of collaborative practices across a range of local and international organisations. The qualitative case studies will involve four to six different sites, each treated as a network centred on an organisation that has successfully employed OSM in recent years. To capture the diversity in successful OSM practice, the project targets case sites that show maximum variation, with ongoing cases shown below:

	Size/ Nature of Organisation	Level of OSM	Location	Nature of product
Case 1	Multinational enterprise	Pre-fabricated flooring	Victoria	Housing, single to five storeys
Case 2	Small/medium enterprise	Transportable housing	South Australia	Housing, single storey, detached
Case 3	Small/medium enterprise	Prefabricated components and structural systems	Tasmania	Housing and commercial, low-rise up to three storeys, detached
Case 4	Startup	Prefabricated timber components	Victoria	Housing, low-rise, detached

Year 2: Model building

Following the case studies, the team will develop a set of collaborative practice models for industry practitioners, combining findings from both existing literature and the case studies. The models will capture and operationalise the relationship between collaboration practices and performance indicators. Performance indicators include total construction time; delivery lead times; wasted time; change scope/change orders; and customer satisfaction/rework. Researchers will examine scenarios before and after OSM implementation to assess changes in performance related to OSM-linked collaboration.

Actors in the network	Interactions within the network	Outcomes of the network
• Key human actors (people, groups of people) • Key non-human actors (objects, legislations, systems, practices, 'rules of the game' etc.)	• Which actors are linked to other actors? • Which actors have power and influence? • Which strategies are used to maintain or change networks?	• OSM barriers and drivers • Collaboration barriers and drivers

Year 3: Model validation and pre-and post testing

To ensure models align with industry priorities and take into consideration relevant factors to guide best practice in OSM implementation, the research team will present the models to a panel of industry experts for validation. The refined models will then be used as the basis for developing practitioner materials in the form of simulation-based training materials. Participants will be recruited to test the simulation scenarios, and outcomes will be used to further test and refine the collaborative practice models.

To receive updates, please contact:

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