A National Multilevel Analytical Research Agenda to support Integrated Construction Supply Chains for Offsite Housing Systems

London, K.A. [12]

[1] *Professor of Construction Management, Director Centre for Integrated Project Solutions, School of Property, Construction and Project Management, RMIT University, Australia*

[2] *Correspnding author's email: Kerry.London@rmit.edu.au*

ABSTRACT

It is often speculated that offsite manufacturing can be an important part of creating a built environment sector that is 'smarter', safer, more efficient and innovative and environmentally 'friendly'. The construction industry often faces various challenges and offsite manufacturing is not the only panacea for the industry ills. However offsite manufacturing can achieve various economic, social and environmental aspirations. The sector is composed of numerous diverse players and this is one of the greatest challenges when initiating transformative changes. This inertia exists with offsite manufacturing. The paper shall discuss the current emergence of a research agenda in Australia. The potential for offsite manufacturing to be an anchor to bring industry and academia together has merit and the *2014 Strategic Roadmap for Integrated Construction Supply Chains for Offsite Housing systems Research Capability* in underpinned by this focus and articulates the priority areas for national and collaborative research over the next five years. The Roadmap was developed with the support of the Australian China Science Research Foundation. The Priority Areas are an important element in strengthening the integration potential and collaborative capacity in the Australian built environment supply chain industrial systems. This Roadmap is concerned with national research projects at a small to medium scale, likely to have a strategic impact on research and industry practice in Australia. It has been developed through an analysis of research that is conducted in other countries that have a maturity in this area, followed by a comparison with Australian research that is missing in our programs currently. This was then aligned with a reflection on the barriers and enablers in current and emerging practice. It is also informed through interviews with leaders in our sector who are grappling with entering the OSM market or who have been engaged in the market for some time. The Department of Industry funded a mission which included a visit to China to analyse a more mature off site manufacturing industry. Nine site visits and interviews with three research institutions and six industry organisations provided date for an international comparative analysis and the Roadmap.

KEYWORDS

construction policy, socioeconomics, international comparative analysis

INTRODUCTION

The Australian housing sector has considerable challenges. It is characterised by lengthening construction times (Gharie et al, 2010), supply shortage (NHSC 2012), and inefficient construction processes (Blismas et al. 2007; BEIIC 2012), which in turn have been linked to craft-based on-site construction techniques and industry fragmentation (Loosemore 2003). Housing construction completion times have increased on average approximately 35% in the last

decade in Australia. The sector faces challenges of productivity, affordability, competitiveness, construction efficiency, safety, waste and innovation. A potential solution to such inefficiencies is the adoption of offsite manufacturing (OSM), the manufacture and preassembly of components before installation into their final location (Goodier & Gibb, 2007). Studies have linked OSM to multiple benefits, including reduced construction times, reduced costs, enhanced worker safety, higher quality and quality control, waste minimisation, improved site management and better quality and affordability (BRE 2004). Then there is other evidence that counters some of these claims and suggests that safety incidents, materials waste and skills shortages problems are simply shifted to another locale and not really solved. Clearly these debates indicate that more rigorous research is needed particularly for the Australian context. Added to this confusion widespread OSM adoption can be hampered by barriers (Blismas et al. 2007), one being the need for extraordinary levels of collaboration and supply-chain integration (London 2008). To date, no large-scale research of offsite manufacturing has been undertaken in Australia, in contrast to Japan, Western Europe and Scandinavia, country leaders in offsite manufacturing in high performance products (Miles & Whitehouse, 2013). In Australia, industry initiatives have been adhoc and poorly documented, apart from a single pilot study (Blismas et al. 2007). From *the outsider's perspective looking in,* the Chinese prefabrication industry appears extremely adept in OSM and has rapidly addressed a rise in demand for multi-unit high rise apartment dwellings in the last decade as China's economy has grown and the migration to urban concentrations has increased. It is useful for us to look to our colleagues in China specifically to observe research and development activities. It is also useful to observe practices by industry and to understand the lessons that they have learned as they grapple with the 'problem of off site manufacturing construction'.

Australian Construction Policy context

The challenges of the industry are not new. The National Built Environment Industry Innovation Council was a team of experts including academics, industry and government established from 2008-2012 as an advisory body to the Australian government and an innovation advocate for the built environment industry. There were ten key recommendations provided by the Council to the Federal government in their final report. Professor London was a member of the Council. The Council was concerned that the industry had deep structural issues that would hinder the sector's productivity growth, innovation and industrial competitiveness. These included '…the fragmented nature of the industry, the resistance to change and the crisis in the materials sector with cheaper alternatives from overseas being specified and installed as preferences to local products. Training and skills development is ad hoc and unlikely to equip a new generation of workers for the future industry skills needed. Rapid adoption of 21st century is needed to transform this traditional focussed industry sector." (BEIIC, 2012). Innovation exists but it is located within silos as individual firms or clusters may innovate but resist sharing with others. The 2012 BEIIC developed a vision of the kind of industry that would emerge in the next 10-20 years and key elements included an industry that would become one that; maximises the time, cost and quality efficiencies of off-site fabrication and assembly and minimises exposure to the on-site variables; actively invests in its own research and development; works to improve quality while reducing costs across the supply chain and serves both domestic and export markets through high end products, materials and skills and to do this it will need to re engineer traditional industry roles to enable integrated project delivery with seamless interaction between innovation, design, fabrication, delivery and assembly; establish a national and internationally

recognised research culture and four major themes were identified and theme 3 was cooperative research and recommendation 8 was Develop a research roadmap for the industry.
This paper describes the Mission project "Integrated international construction supply chains: knowledge cluster for seamless off-site housing systems (ACSRF15100) and the development of a national Research roadmap funded by the Federal government through the Department of Industry Australia-China Science Research Fund. The aim was to promote collaboration with Chinese research institutions to initiate long-term research partnerships on off-site housing system practices to improve knowledge creation and transfer. The outcomes were research workshops; development of industry -academic linkages, reports and a website. The three reports included: Industrialised Building in the Housing Sector - Lessons Learned, Industrialised Building in the Housing Sector - Current State in Australia and Industrialised Building in the Housing Sector – 2014 Strategic Research Roadmap for Offsite manufacturing. A significant outcome was the initiation of a Knowledge Cluster between Harbin Institute of Technology, Tsinghua University and RMIT University and now expanded to include: Dalian University of Technology, the Australian Housing Supply Chain Alliance, the Beijing Building Construction Research Institute and Purdue University (refer website: industrialisedbuilding.com.au). This paper is limited to describing the results of the Mission study led by Professor London.

METHODOLOGY

The 2014 Roadmap has been developed through an analysis of research that is conducted in another country (China) that has a maturity in this area, followed by a comparison with the research that Australian researchers have been able to conduct and which is clearly missing in our programs of research currently. This was then aligned with a reflection on the barriers and enablers that have been observed in current and emerging practice. Therefore the Roadmap is informed by the Literature Review as well as the Lessons Learned Mission to China report including interviews/focus group interviews with our Chinese colleagues both in academia, industry and government. It is also informed by interviews, consultations and discussions with leaders in our Australian sector who are grappling with entering the OSM market or who have been engaged in the market for some time and the challenges that they have faced.

RESULTS

The lessons learned are in both industry practice as well as research. We visited Harbin University and Tsinghua University shared our research programs and potential projects.

Organizations	Dates	Activities	Attendees
Harbin Institute of Technology	19th Feb	Workshop	6 HIT academic staff, 2 RMIT staff, 6 HDR students
	19th Feb	Seminar	3 HIT academic staff, 2 RMIT staff, 14 HDR students
	19th Feb	Public lecture	6 academic HIT staff, 2 RMIT staff, 12 HDR students, 4 industry practitioners
Tsinghua University	21st Feb	Workshop	8 TU academic staff, 2 RMIT staff, 2 Australian practitioners 6 HDR students, 1 researcher Beijing BCRI
	21st Feb	Public lecture	6 TU academic staff, 2 RMIT staff/ 2 Aus. Practitioners, 18 HDR students, 4 CIOB members, 4 industry practitioners
Total Participants Workshops			107

Seven organisations were visited after the visits to the Universities. All the organisations were located in Beijing. Table 2 summarises the organisations that were visited.

Organizations visited	Dates	Activities	Attendees	
			Australia	China
Case study 1 Research Institute	22nd Feb	Workshop	Prof. Kerry London ---RMIT Peng Zhang--- VAKIP Adam Siegel ---Metricon Ray Thompson--CSR	Senior Engineer with 5 staff of this institute
Case study 2: Manufacturing, Concrete products	22nd Feb	Interview Visit factories	As above	Deputy General Manager/Chief Engineer
Case study 3: Manufacturing, Modular housing	24th Feb	Interview Visit factories	As above	Marketing Manager
Case study 4: Developer, High rise apartments	24th Feb	Interview	As above	Chief Engineer, Dept of construction management
Case study 5 Manufacturing, Modular housing and Temporary accommodation	25th Feb	Interview Visit factories	As above	General Manager
Case study 6 Manufacturing, Modular housing	25th Feb	Interview Visit factories	As above	Operation Manager
Case study 7 Research institute	26th Feb	Workshop	As above	Division Chief MHURD of China,

Table 2 Visits and interviews to organisations involved in industrialised building

Summary

An important difference between China and Australia is that off site manufacturing is termed Industrialised Building (IB) and this is similar to our experiences in conducting research in Malaysia. In China, in the 1970s industrialised building became an important way of thinking to solve the problem of leaks in high rise apartment buildings. It was considered that on site construction work practices were the problems and that more quality control was needed by developing products and systems in a controlled factory environment. In the last 5 years two other important factors began to emerge as key challenges construction stakeholders needed to address namely; 1) labour costs were beginning to rise and 2) environmental sustainability problems and in particular energy consumption and air quality in highly populated urban concentrations. Industrialised building once again became an important area of focus. A White paper was developed five years ago by Professor Ma on industrialised building which gave direction to the policy development and the new 5 Year Agenda on Industrialised Building. There is a strong connection between the research organisations, research conducted on the concepts of Industrialised buildings and Building Information Modelling and the industry policy developments – there is close liaison and support for the research. It was considered that on site construction work practices were the problems and that more quality control was needed by developing products and systems in a controlled factory environment. There were three key areas where we could pursue future research collaborations with Harbin University: Analysis of adoption patterns, growth and productivity impacts of the Industrialised Building approach (subsectors) and associated emerging & enabling technologies (BIM, 'Green',) across China and Australia; Examination of regulations, standards and specifications to support BIM adoption and

Skills Development and Skills Deficiencies. The RMIT Centre for Integrated Project Solutions is characterized by humanities based research approaches derived from management sciences, social sciences, economics and organisational studies and Professor Ma's approaches are technical systems based computer logic approaches. However a commonality is the applied nature of both groups and in particular action research methodologies underpin both areas. Both research groups have close relationships with industry organisations. There were three key areas which we could pursue future research collaborations with Tsinghua University: Collaborative Platforms Solutions for Integrated Project Delivery; Examination of market incentives, regulations, standards and specifications to support BIM adoption and Quality Assurance Systems (refer to the final report for further detail). Whilst in China, the Australian Mission participants visited seven organisations : two research institutes; a concrete product manufacturing factory; three modular housing manufacturing factories and the largest developer of high rise apartment dwellings. The research institutes have conducted extensive technical research on materials and system and contribute to informing the government extensively on policies and regulations and some key lessons learned can be summarised collectively as: lack of highly skilled labour; industrialised building does not increase overall 'costs' specifically indirect costs of time and materials, overheads and rectification of error onsite are reduced and so overall profitability is higher. Therefore affordability to end consumer is achieved. To date research has not been published that measures exactly the direct vs indirect cost model nor the business profitability and housing affordability model. We have also found in China that the increase of direct cost of using prefabricated systems was 20%, 5 years ago and is now reduced to 2%. Efficiencies are gained as all actors along the supply chain learn the new technology. Non technical research is needed to improve adoption of industrialised building. These institutes are not focussed on doing this at the moment but recognise its value and need. False propaganda of some companies. For example, one company for advertising purposes announced that they very fast constructed a steel high rise building in Shanghai. However, the technology is still immature and not ready for such wide scale production. Steel construction is not common for high rise apartment buildings. This can not be repeated on a feasible scale and is not widely supported. BIM policy and regulation research is also needed. Lessons learned from Modular housing stakeholders interviewed are organised around challenges and innovations;

Challenges	**Innovations:**
When exporting a challenge is gaining certification from foreign countries' government, and meeting foreign countries' regulations, standards and requirements	Transferring from manufacturing components (i.e. Panels) of house to completed prefabricated house Pre-assembled system for quality assurance Company trains labourers on site to install and sends supervisors to overseas projects to ensure quality control
Transportation delays impact servicing of contracts, increase lead times and affect profitability, company credibility	Companies import advanced technology and machinery from developed countries, i.e. Italy, Spain, NZ and then adapt and modify machinery and equipment to suit actual needs; little equipment technology created inhouse and little connection to the research institutes
Product upgrading is very slow.	
Profitability is decreasing because of the increase in competition	Chinese domestic market is increasing and so there is a subtle shift to international and domestic markets.
Industry Policy on land use for detached housing is not conducive to this market	Key international markets have included disaster and temporary accommodation for refugee camps (WorldBank funded) and mining and remote construction accommodation markets; emerging domestic market is for upmarket homes
Communication with clients on design; changes of design and scope; lack of communication between design and construction units & drawing errors	

The interview with the high rise apartment developer provided the following themes.

Challenges:	**Innovations**
No support in the beginning for development/ adoption of new technology	Improved management skills and quality of products by using IB technology
Little policy/regulation on new technology and standards	Better quality control by using industrialized building technology and reduction in the errors from 'cm' level to 'mm' level.
Cost on generating new technology	
Lack of technologies	
Lack of skills across range of stakeholders; labours/traders/professionals; suppliers don't know new technology nor how to make components; difficult in design stage to make sure all parts are matched	Company is leader in prefabrication and IB processes
	Design rationalisation/ constructability through product standardization
Size of the parts can vary and are difficult to manufacture	
Increased cost of building. Increase by 100-500RMB/m^2	Leader in BIM; although still in infancy

Commentary on current state and adoption challenges in Australia

During the Mission we conducted interviews with various industry players in the housing sector to obtain their insights on the current state and the adoption challenges. The following is a summary of the commentary. There is currently an industry interest in off site manufacturing in the Australian housing sector from two directions: supply vs. demand, i.e. those supplying the products and/or systems and those procuring the products and/or systems.

Supply challenges	Demand challenges
Insufficient demand from the housing sector (namely contractors) to ensure economic profitability and at least a return on investment	Assurance in quality
	Lack of technical knowledge for onsite installation
Stability in the market i.e. demand over a number of years	Lack of predictability and standardization of construction methodology in start-up phases to ensure increased efficiencies improving site productivity; decreasing overall construction time
Fear of being innovator (first to market) only to have technology copied before ROI is achieved	Integrated construction systems to reduce number of subcontractors onsite and site coordination
Fear of imported products/systems that are less costly	Achieve sustainability ratings
Economic risk in start-up capital costs for land and factory	Depending upon the type of product and/or system a nervousness of equivalent quality provided by alternatives
Lack of knowledge of technology and thus investment in research and development required slow uptake by house builder	Difficulties in obtaining compliance of new products/systems
Lack of onsite capability to problem solve for new products/systems installation	Complexities of obtaining compliance approvals across states with different regulations & trade capabilities
Unexpected site constraints delay installation	
Lack of compliance to current regulations and thus increased time to negotiate new approvals for compliance	Completed modular housing systems respond to consumer/user expectations
	Cost of alternative product/system does not affect the price point for a particular customer range
New products/systems bring with it new challenges	Lack of Building Information Modelling

CONCLUSION

This Roadmap is concerned with national research projects at a small to medium scale, likely to have a strategic impact on Australian research. The Roadmap established a number of priority thematic areas for investment. In the development of the Roadmap, current capabilities were not audited although that would be a useful activity to undertake.

NATIONAL RESEARCH ROADMAP: PRIORITY RESEARCH AREAS

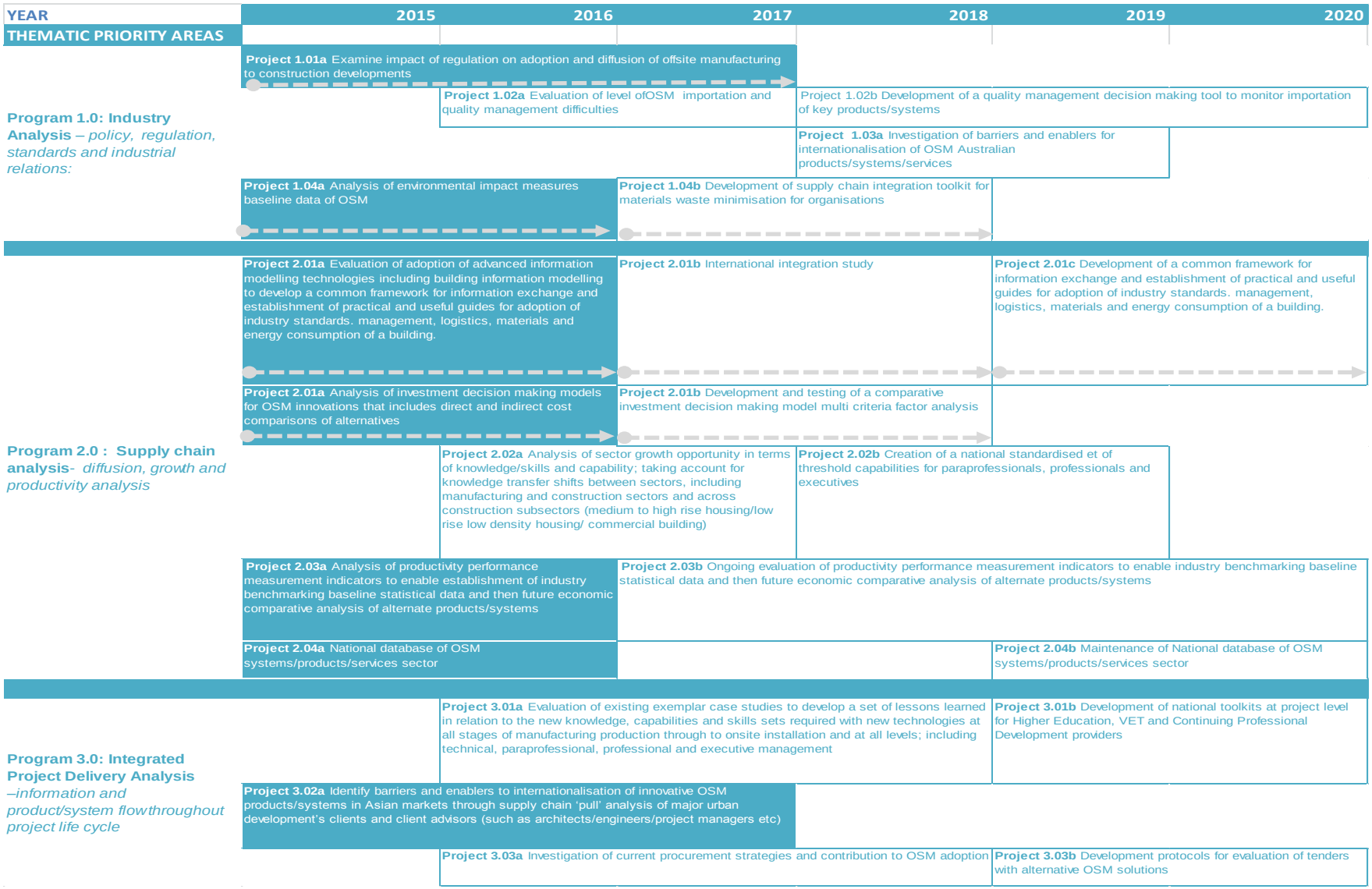

Figure 1 National Research Roadmap on Thematic priority research areas 2015-2020.

Through our Industrialised Building Knowledge Cluster we shall continue to strengthen the visibility of the OSM research being undertaken in Australia and with our international collaborators as we now have a 3 year ARC Linkage project on this topic. The Knowledge Cluster will provide a platform for dissemination of OSM research activity at the partner institutions. Subsequent to this other research institutions have been invited to be part of the Knowledge Cluster as they undertake research in OSM and are particularly engaged research in this region. We are pleased to be able to say that Dalian University of Technology, Beijing Building Construction Research Institute and Purdue University are all now members of the Cluster. We need to build these international links as currently there is a dearth of researchers in Australia engaging in OSM research. Although the Knowledge Cluster was primarily about connecting RMIT with Harbin and Tsinghua knowledge resides not only in the research institutions but also in leading practices, various industry groups and associations. The membership was widened to include other industry members. Whilst the Roadmap looks forward over the next five years, it is important periodically to consider new and emerging areas in the research environment requiring national scale investment. Consultative roadmapping should be undertaken every 2-3 years.

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