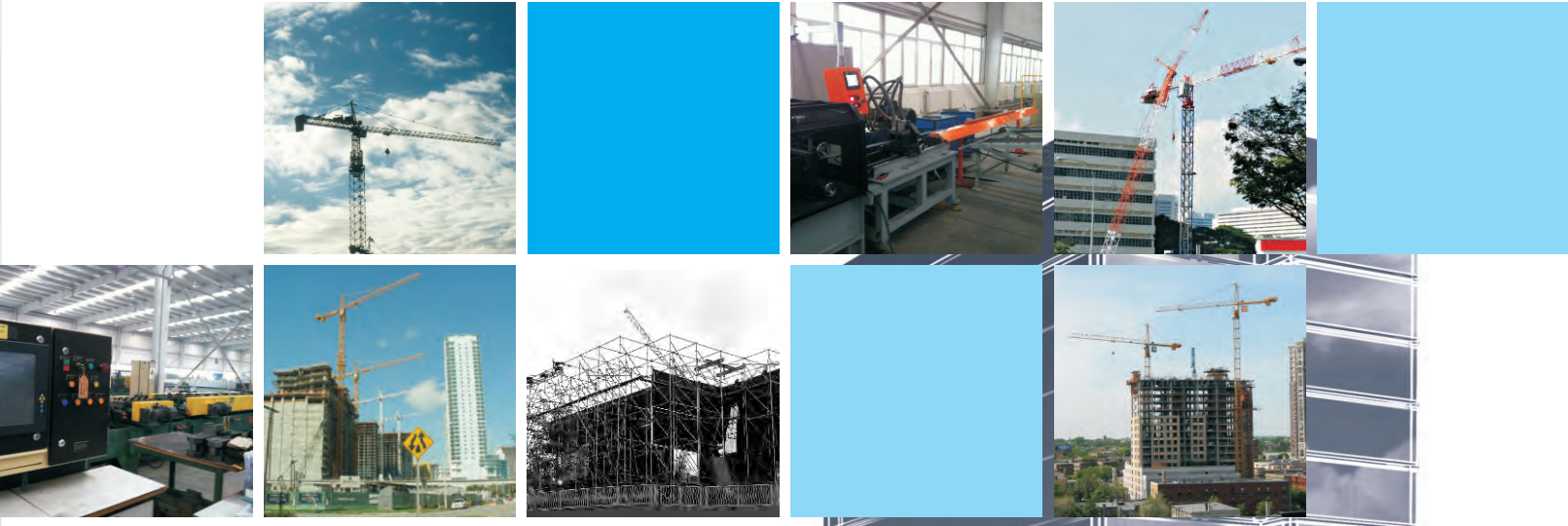




Australian Government
Department of Industry



Industrialised Building in the Housing Sector — Lessons Learnt

Collaboration with Tsinghua University and Harbin Institute of Technology to develop integrated international construction supply chains: knowledge cluster for seamless off-site housing (OSH) systems

Research Report 1 prepared for Department of Industry
by the Centre for Integrated Project Solutions

KLondon
PZhang
TMaqsood
MKhalfan

May 2014



Integrated International Construction Supply Chains: Knowledge Transfer for Seamless Off-site Housing Systems

Lessons Learned Report

May 2014

Authors:

Professor Kerry London

Mr Peng Zhang

Associate Professor Tayyab Maqsood

Associate Professor Malik Khalfan

Research Program: Australia-China 2013 - 2014 group missions



Centre for Integrated Project Solutions



All intellectual property in the ideas, concepts and design for this publication belong to the research academics who authored the report.

All rights are reserved.

ISBN 978 0 9925377 0 8

Citation for this report: London, K., Zhang, P., Maqsood, T. & Khalfan, M. (2014) *Research report for Department of Industry: Industrialised Building in the Housing Sector---Lessons Learned*, Centre for Integrated Project Solutions, RMIT University, Melbourne, Australia.

ACKNOWLEDGEMENT

This monograph represents the results of a nationally competitive research grant funded by the Department of Industry, Australia China Science and Research Fund and we are grateful to the Department of Industry. The authors wish to acknowledge our colleagues at Harbin Institute of Technology, Professor Xiaolong Xue and Tsinghua University, Professor Zhiliang Ma. We also appreciate the support and encouragement for our China research visit provided by Mr Chenguang Li, Beijing Building Construction Research Institute (BBCRI). Finally we are grateful for the insights provided by many of our industry and academic colleagues who have provided their time to be interviewed or have provided feedback on the various reports.

We especially thank Mr Adam Siegel, from Metricon and Mr Ray Thompson, CSR who accompanied Professor London and Mr Peng Zhang on the China Mission and provided invaluable insights and comparisons between Australia and China.

A key outcome of this research project was the creation of a knowledge cluster and we have now created a website for this which we anticipate will have longevity beyond the life of this project and prove useful to academics, industry, policymakers and various other stakeholders involved in the difficult area of off site manufacturing (industrialised building) for the Australian housing sector.

Although we acknowledge various input we also take responsibility for any remaining deficiencies which are the final responsibility of the authors. We interviewed numerous participants and we have triangulated between primary data, our experiences, local literature and international literature as much as possible to arrive at our interpretations and inferences; we were rigorous in our critique - however the quality of our work also lies in the hands of the quality of the material we were sourcing. We gratefully acknowledge the following colleagues:

Name	Organisation
Professor Xiaolong Xue	Harbin Institute of Technology
Professor Zhiliang Ma	Tsinghua University
Mr Chenguang Li	Beijing Building Construction Research Institute
Miss Lingna Li	Beijing Building Construction Research Institute
Mr Qinjian Jiang	Beijing Yugou
Mr Wei Xu	DB Prefab-house
Mr Jianshu Li	Beijing Vanke
Miss Yan Yan	Housespace Prefab
Mr Wangjiao Chen	BNBM Homes
Mr Ming Ye	Ministry of Housing and Urban-Rural Development, China
Mr Rob Anderson	Anderson Consulting, Chair Australian Housing Supply Chain Alliance
Mr Adam Siegel	Metricon, Member Alliance
Mr Ray Thompson	CSR, Member Alliance
Mr Michael Meehan	Australand, Member Alliance
Marie Lakos	FMG Engineering, Member Alliance
Russell Woods	Member Alliance
Philip Alviano	Master Builders Association, Alliance

Table of Contents

1	Executive summary	1
2	Introduction	5
3	Research-related workshops & symposia with Chinese partner/s	8
3.1	Harbin Institute of Technology	9
3.1.1	Research capability	9
3.1.2	comment on research alignment and opportunities	9
3.1.3	Future Program and/or Projects	11
3.2	Tsinghua University	11
3.2.1	Research capability	11
3.2.2	Areas for further research	12
3.2.3	Future Program and/or Projects	13
4	Research-industry mission to China	14
4.1	Case study 1 Research institute	15
4.1.1	Organisation Background	15
4.1.2	Challenges	16
4.1.3	Innovations	16
4.1.4	Uniqueness/Expertise	16
4.2	Case study 2	17
4.2.1	Organisation Background	17
4.2.2	Challenges	17
4.2.3	Innovations	18
4.2.4	Uniqueness/Expertise	18
4.3	Case study 3	19
4.3.1	Organisation Background	19
4.3.2	Challenges	19
4.3.3	Innovations	20
4.3.4	Uniqueness/Expertise	20
4.4	Case study 4	21
4.4.1	Organisation Background	21
4.4.2	Challenges	21
4.4.3	Innovations	22
4.4.4	Uniqueness/Expertise	22
4.5	Case study 5	23
4.5.1	Organisation Background	23
4.5.2	Challenges	24
4.5.3	Innovations	24
4.5.4	Uniqueness/Expertise	24
4.6	Case study 6	25
4.6.1	Organisation Background	25
4.6.2	Challenges	26
4.6.3	Innovations	26
4.6.4	Uniqueness/Expertise	26
4.7	Case Study 7	27
4.7.1	Challenges	27
4.7.2	Innovations	27
	Appendice National Benefits and success indicators	28

List of figures

- Figure 1 Componentry in Industrialised Building
- Figure 2 Integrated Construction Supply Chains: Communication and Collaboration- Building Information Modelling
- Figure 3 Multi unit high rise apartments
- Figure 4 Main gate of HIT
- Figure 5 School of Management, HIT
- Figure 6 Professor Xue presenting on BIM adoption
- Figure 7 Professor London presenting on E Business & Collaborative Platforms Projects
- Figure 8 Professor Ma presenting
- Figure 9 Ray Thompson presenting on behalf of CSR
- Figure 10 Adam Siegel presenting on behalf of Metricon
- Figure 11 Ray Thompson presenting on innovation
- Figure 12 Adam Siegel presenting on sustainability action research project
- Figure 13 Tsinghua Workshop
- Figure 14 Collaborative BIM
- Figure 15 Ongoing RMIT projects
- Figure 16 Case study 1 Headquarters
- Figure 17 Case study 1 project
- Figure 18 Prefabricated structural concrete products at case study 2 factory yard
- Figure 19 Prefabricated structural concrete products at case study 2 factory yard
- Figure 20 Example of a Prefabricated House from case study 3
- Figure 21 Manufacturing facilities of case study 3
- Figure 22 Case study 4 head office
- Figure 23 Case study 4 project multiunit high rise apartment building
- Figure 24 Example of case study 5 modular housing product
- Figure 25 Typical modular housing product from case study 5
- Figure 26 Case study 5 modular temporary office accommodation
- Figure 27 Case study 5 factory facilities 'flat pack' type production
- Figure 28 Case study 6 typical modular housing product
- Figure 29 Case study 6 typical modular housing product
- Figure 30 Case study 6 factory: 'flat pack' modular housing walls
- Figure 31 Case study 6 'flat pack' wall framing construction

List of tables

- Table 1 Mission Activities
- Table 2 China Mission Academic Events
- Table 3 Visits and interviews to organisations involved in industrialised building

1 EXECUTIVE SUMMARY

The Lessons Learned are in both industry practice of industrialised building as well as academic research. We visited Harbin Institute of Technology and Tsinghua University and we shared each of our research programs and discussed potential future projects. An important difference between China and Australia is that off site manufacturing (OSM) is termed Industrialised Building. 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 Institute of Technology:

1. 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

- Baseline historical analysis in relation to policy events and documents and impact upon adoption and sector growth.
- Analysis of perceptions including industry and end users stakeholders.
- Development of centralised data collection to profile, monitor and evaluate the productivity and growth of the off site manufacturing subsectors.
- Cross country comparison of factors affecting adoption and growth of the sector including market structure, firm conduct and government intervention.
- Sustainability evaluation of claims of increased sustainability of pre-fabricated buildings and the products.
- Urban Health of industrialised building on densely populated cities including pressure on transport infrastructure and improvements in air quality.
- Investigation of constructability issues, efficiencies and productivity improvements in common and innovative industrialised building scenarios.
- Creation of indices and metrics to evaluate inputs (integration capability/technical skills/start up costs/ policy instruments) against outputs (efficiency/industry fragmentation/disputes/'smart' industry/ urban health/OHS/sustainability)

2. Examination of regulations, standards and specifications to support BIM adoption

- Development of an inventory of cross country comparison of similarities and differences in BIM and Industrialised building standards.

- Identification of current practices in each country.
- Evaluation of impact of disharmonisation of regulations on import and export

3. Skills Development and Skills Deficiencies

- Identification of skills deficiencies and/or perceived deficiencies
- Analysis of executive management leadership capability, knowledge, skills and competencies in Business Development and Financial Feasibility
- Evaluation of professionalization of project management throughout the house project life cycle
- Examination and creation of Building Information Modelling and Industrialised Building: Global curriculum for improved knowledge sharing and student mobility between the two countries
- Appraisal of 'readiness' of the industry to embrace construction supply chain integration environments to support skills development

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:

1. Collaborative Platforms Solutions

- Evidence based comparison of cost estimating impact on projects
- Evaluation of BIM based collaborative system for integrated project delivery targeted to offsite housing systems and products including export and import standards
- Developing metrics for sustainability using industrialised building approaches
- Integrating project management legacy systems and Building Information Modelling

2. Examination of market incentives, regulations, standards and specifications to support BIM adoption

- Identification of current practices in each country
- Market incentives vs government regulation to increase BIM adoption and industrialised building systems

3. Quality Assurance Systems

- Identification of IT Systems to support product flow
- Analysis of contribution BIM Harmonisation can make to Materials Stewardship

Whilst in China, the Australian Mission participants visited the following 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:

1. Lack of highly skilled labour
2. Industrialised building does increase the initial capital cost of buildings however it is more complex than this. It is capital cost and this does not take into account the efficiency gains (productivity improvements) nor any other indirect, hidden costs or life cycle reductions. This has been a significant argument against industrialised building in Australia but the lesson from China is that when comparing direct cost between traditional vs OSM, the OSM systems procurement by

contractor to supplier is more expensive. However, the Chinese stakeholders interviewed stated that 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. We would anticipate similar efficiencies in the Australian residential housing supply chain once adoption rates have improved.

3. Non technical research is needed to improve adoption of industrialised building. Some companies do not realize the potential benefits of the industrialised building, i.e. reducing labour cost, increasing efficiency and increasing safety on site. These institutes are not focussed on doing this at the moment but recognise its value and need. This is a potential area where RMIT's Centre and Harbin Institute of Technology can collaborate immediately as adoption of new technologies is a strength of both research clusters.
4. False propaganda of some companies. For example, one company for advertising purposes announced that they constructed a steel high rise building very quickly 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 cannot be repeated on a feasible scale and is not widely supported.
5. BIM policy and regulation research is needed in relation to BIM and industrialised building for the housing sector. Building Information Modelling is an important part of their future research program in industrialised building.

Lessons learned from the Modular housing stakeholders interviewed are combined and organised around challenges and innovations and include;

Challenges:

1. When exporting one of the greatest challenges is gaining certification/ license from the foreign countries' government and Identification and meeting foreign countries' regulations, standards and requirements.
2. Transportation is key to the exporting of products and problems, i.e. delays can impact the servicing of contracts and increase lead times and affect profitability on projects and ultimately company reliability and credibility.
3. Product upgrading is very slow.
4. Profitability is decreasing because of the increase in competition.
5. Industry Policy in regards to land use for detached housing is not conducive to this market.
6. Communication (various forms);with clients about design including changes of design and changes in scope and lack of communication between design and construction units and errors on construction drawings.

Innovations:

1. Transferring from manufacturing components (i.e. Panels) of the house to the whole completed prefabricated house
2. Pre-assembled system to check if the parts are matched or not before installation
3. Company trains labourers on site to install and sends supervisors to overseas projects to ensure quality control .
4. Companies import advanced technology and machinery from developed countries, i.e. Italy, Spain,

New Zealand and then companies adapt and modify the imported machinery and equipment to suit their actual needs; little or no equipment technology created in house and little connection to the research institutes.

5. The Chinese domestic market is gradually increasing and so there is a subtle shift in focussing on both international and domestic markets.
6. Key international markets have included disaster and temporary accommodation for refugee camps and these contracts are largely funded by WorldBank etc. and then markets such as mining and remote construction accommodation – the emerging domestic market is for upmarket residential homes.

The interview with the high rise apartment developer provided

Challenges:

1. In the early stages there is little or no support for the development and adoption of the new technology (BIM, Prefab, industrialized building, etc.)
2. Little or no policy or regulation in regards to new technology and new standards
3. Cost on generating new technology and feasibility studies
4. Lack of technologies
5. Lack of skills across the range of stakeholders including labours/traders/professionals; suppliers don't know the new technology and don't know how to make the components; the designers don't know how to design this kind of building (It is difficult in the design stage to make sure all the parts are matched)
6. The size of the parts can vary and it is difficult to manufacture effectively. More errors in the joint part would be caused.
7. Increased cost of building. The cost can increase by approximately 100-500 RMB per m².

Innovations:

1. Improved management skills and quality of products by using industrialized building technology
2. Better quality control by using industrialized building technology and reduction in the errors from 'cm' level to 'mm' level.
3. Company is the leader in prefabrication and industrialised building processes
4. Design rationalisation and constructability through product standardization
5. Leader in Building Information Modelling; although still in its infancy

2 INTRODUCTION

The group mission sought to initiate an Australian-China Knowledge Cluster to identify barriers and enablers for export and import of a range of construction systems and products which support economic, social and environmental objectives for all stakeholders. Table 1 Summary of Economic, Environmental and Social National Benefits (Appendice 1) summarises the measures and success indicators in relation to the short term within the life of the mission and then also the longer term benefits - should recommendations be implemented.

The Australian housing sector has considerable challenges. There is some evidence that suggests that off-site manufacturing (OSM) solves problems related to quality and quality control, affordability, construction delays, low customer satisfaction, skills shortages, waste minimisation, poor site management and high levels of safety incidents. 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. Affordability is also a complex topic and one that needs much more attention that it has received to date, because there is such a lack of economic modelling and very few published case studies of business models that relate to the Australian construction industry. Clearly these debates indicate that more rigorous research is needed particularly for the Australian context.

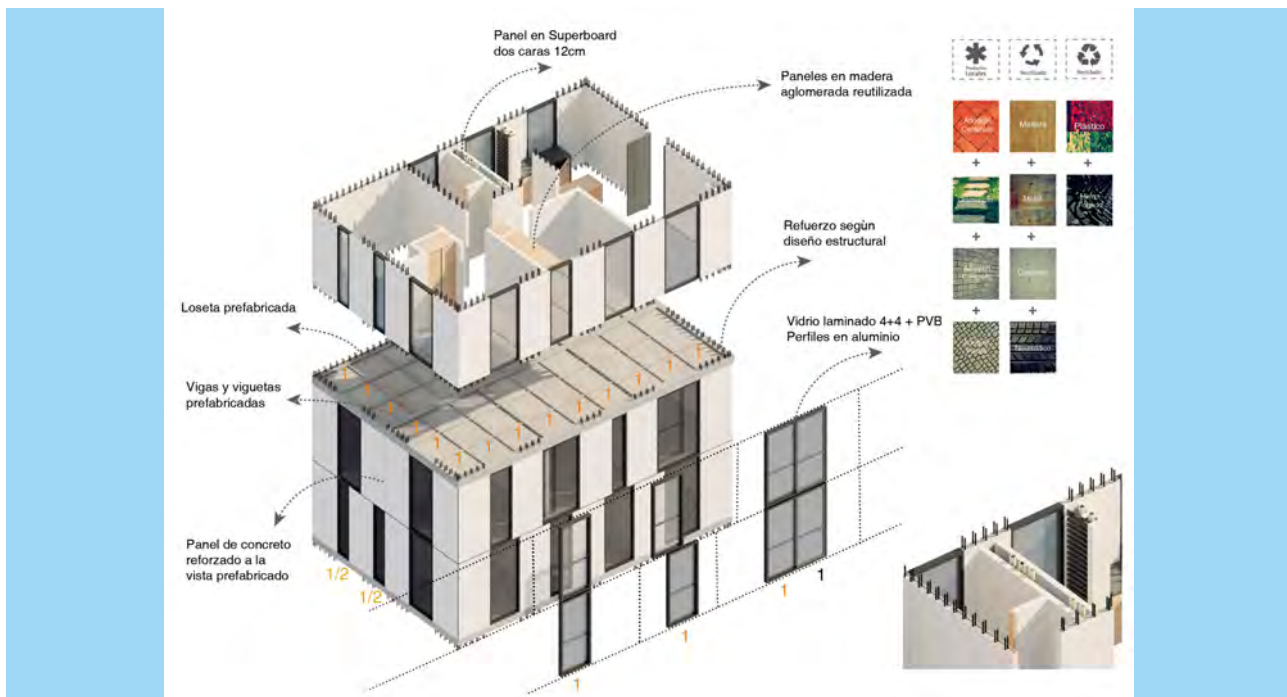


Figure 1 Modularisation in Industrialised Building

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. OSM has been considered an answer to this industry problem although there has been little material effect, however there are a few exemplars.

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'. It is important to note one of our immediate lessons learned was that similar to our experiences in conducting research in Malaysia and interacting with our Malaysian colleagues, the term 'off site manufacturing' was not generally used but instead the term 'industrialised building is used'.

Professor London is a founding member of the Australian Housing Supply Chain Alliance. The alliance was formed in 2010 and brings together manufacturers, housing developers/builders, an engineering consultant, a university, industry associations and a government regulator. The aim is to conduct research and development to better understand factors affecting improved integration of the construction supply chain. This nexus of academia, industry and government allows an immediate and active reflection of theory and practice and it replicates many other such world class models seeking to improve industry sectors through industry-academic linkages. Applied research is an important part of all three Universities involved in this mission and therefore close collaboration with industry and government is central to our future work. Therefore the mission involved academics and practitioners representing the Alliance. This triggered conversations involving critique and debate on the activities that were observed whilst on the mission.

Our mission was to explore better ways to develop Integrated housing supply chain systems. There has been discussion about supply chains for fifteen years in the construction management research community (London, 1999) and yet it is still a difficult and challenging concept for industry practitioners who have 'grown up' in the industry. There is quite a great deal of supply chain theory and practice literature and our team has extensive expertise in specific topics. We have published widely on this topic for fifteen years – we do not intend to replicate that work when exploring the lessons learned in this report although it will provide important information for the website for this Knowledge Cluster. For our mission integrated housing supply chain systems refers to integration in relation to communication and collaboration; and we were specifically interested in the uptake of Building Information Modelling.



Figure 2 Integrated Construction Supply Chains: Communication and Collaboration- Building Information Modelling

The following discussion provides summaries of results of a series of interviews and site visits conducted in 2014 in China by Professor London and Mr Peng Zhang; where we observed, reflect and speculated on implications for the Australian context. The mission activities are summarised in Table 2 Missions Activities and include;

1. Research-related workshops and symposia with Chinese partner/s
2. Research-industry mission to China
3. Knowledge Transfer Documentation

This Lessons Learned report is a result of activity 1 and 2.



Figure 3 Multi unit high rise apartments

ACTIVITY DESCRIPTION	
Activity 1 Research-related workshops and symposia with Chinese partner/s	
Description	Outcome
To conduct a joint public guest lecture event, lecture for student and staff workshops during the group mission visit to China (two each at both Tsinghua and Harbin universities)	<p>Through the workshops and guest lecture, universities involved would be able to better understand the research activities at each institution. It would also give opportunities to all partners to identify key areas for further research with each other on long-term basis. This activity would also result in:</p> <ul style="list-style-type: none"> • Ongoing research activity aligned to Research Roadmap - Well attended seminars (200 students & 75 invited guests) that create increased awareness & stimulates debate • Publication of Papers
Activity 2 Research-industry mission to China	
Description	Outcome
To visit the relevant offsite manufacturing facilities during the group mission visit to China (both in Beijing and Harbin cities)	The visit to the offsite manufacturing facilities sites (at least two) would elicit knowledge (explicit and tacit) and this would result in the development of shared expertise on innovative supply chain integration systems for pre-fabricated and modular construction activities. The investigation will be undertaken using a knowledge management methodology and help identify different types of knowledge.
Activity 3 Knowledge Transfer Documentation	
Description	Outcome
It is very important to capture, share, transfer, and document knowledge related to the OSM acquired before, during and after the visit of the group mission.	<p>The following are the reports which the research team will be producing and make available via the developed website:</p> <ul style="list-style-type: none"> • Report on current state of OSM in Australia including niche and specialised OSM activities including pre-fabricated and modular construction • Lessons Learnt during the visit • OSM Research Roadmap

Table 1 Mission Activities

3 RESEARCH-RELATED WORKSHOPS & SYMPOSIA WITH CHINESE PARTNER/S

The mission was undertaken over ten days in February 2014. The activities conducted at Harbin Institute of Technology included a workshop, seminar and public lecture on 19th February 2014. A workshop and public lecture were also undertaken at Tsinghua University on 21st February 2014 and a research meeting between Professor Ma and Professor London. Through the workshops and public lecture, universities achieved an understanding of the research activities at each institution. Key areas for further research between universities on a longer term basis were identified. More than 100 participants were involved in the various activities at the two Universities. Professor Xue and Professor Ma were instrumental in organising these activities and the Chartered Institute of Building in Beijing, was also supportive in communicating to their members.

Organizations visited	Dates	Activities	Attendees	
			Australia	China
Harbin Institute of Technology	19 th Feb	Workshop	Prof. Kerry London ---RMIT Peng Zhang---VAKIP	6 HIT academic staff 2 RMIT staff 6 HDR students
	19 th Feb	Seminar	Prof. Kerry London ---RMIT Peng Zhang---VAKIP	3 HIT academic staff 2 RMIT staff 14 HDR students
	19 th Feb	Public lecture	Prof. Kerry London ---RMIT Peng Zhang---VAKIP	6 academic HIT staff 2 RMIT staff 12 HDR students 4 industry practitioners
Tsinghua University	21 th Feb	Workshop	Prof. Kerry London ---RMIT Peng Zhang---VAKIP Adam Siegel ---Metricon Ray Thompson--CSR	8 TU academic staff 2 RMIT staff 2 Australian practitioners 6 HDR students 1 researcher from Beijing Building Construction Research Institute
	21 th Feb	Public lecture	Prof. Kerry London ---RMIT Peng Zhang---VAKIP Adam Siegel ---Metricon Ray Thompson--CSR	6 TU academic staff 2 RMIT staff 2 Australian practitioners 18 HDR students 4 CIOB members 4 industry practitioners
Total Participants Workshops				107

Table 2 China Mission Academic Events

3.1 HARBIN INSTITUTE OF TECHNOLOGY

3.1.1 RESEARCH CAPABILITY

Professor Xue is Director of the Centre for Engineering Behavior and Sustainability (CEBS) and Mobile Construction Lab (iCons) which is located within the Department of Real Estate and Construction Management, School of Management in Harbin Institute of Technology.



Figure 4 Main gate of HIT



Figure 5 School of Management, HIT

His current research program includes leading four projects which are funded by the National Natural Science Foundation of China and the National 12th Five-year Plan Key S&T Project of P.R. China;

1. *Innovation on foundational management theory and method for mega infrastructure engineering.* (National Natural Science Foundation of China, 2014-2018, Co-PI)
2. *Effect mechanism of team cognition on team performance in construction project: A longitudinal study.* (National Natural Science Foundation of China, 2013-2016, Principal Investigator)
3. *Sustainability Evaluation of Prefabricated Buildings.* (The National 12th Five-year Plan Key S&T Project of P.R. China, 2013-2015, Principal Investigator)
4. *Emerging technology acceptance and absorptive capacity: Team learning and innovation for sustainability in the AEC industry.* (The Program for New Century Excellent Talents in University, Ministry of Education, China, 2012-2014, Principal Investigator)

3.1.2 COMMENT ON RESEARCH ALIGNMENT AND OPPORTUNITIES

According to Professor Xue there are quite a few overlaps in the two programs of research conducted by CEBS and CIPs. Both countries face similar challenges in construction industry performance. The specific Chinese issues include: reputation in relation to quality, environmental and energy impacts, sustainability problems in life cycle and follower of technology innovation and industrial development of the manufacturing industry. Building Information Modelling has potential to solve many of these issues as they rely upon improved communication and collaboration; which appears to be a root cause for many of the perceived challenges of the industry.

Professor Xue is undertaking some research projects in relation to BIM in order to find out how to effectively and efficiently adopt and use these emerging technologies (BIM) to improve the life cycle performance (sustainability) of buildings and infrastructures, and the underlying mechanisms which affect the adoption of emerging technologies (BIM). There is potential for further research cooperation between Professor London's and Professor Xue's research Centres on BIM adoption.

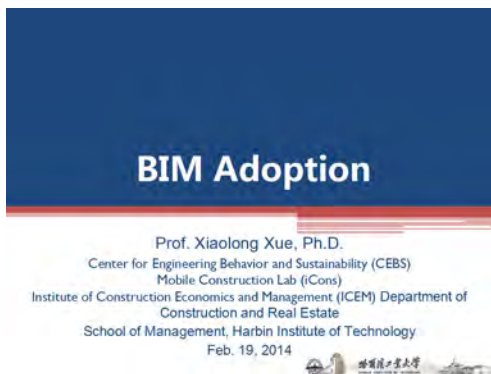


Figure 6 Professor Xue presenting on BIM adoption



Figure 7 Professor London presenting on E Business & Collaborative Platforms Projects

Professor London has already conducted two national studies through the CRC Construction Innovation whilst at University of Newcastle namely; *Collaborative Platform Solutions* (with University of Newcastle academics Dr Ning Gu, Dr Vishal Singh and Associate Professor Brankovic and Ms Claudelle Taylor at Leighton Holdings Group) and *eBusiness Adoption of Innovation Information Technologies* (with RMIT Dr Guillermo Aranda Mena and Professor Ron Wakefield). These two studies focussed on the challenges of adoption of Building Information Modelling for innovators and early adopters and then the second study was for later adopters or laggards.

Coupled with this more recently the RMIT team lead by Professor London and including Associate Professor Maqsood and Associate Professor Khalfan and another CIPS member, Dr Peter Wong, are currently conducting a funded study on *Construction Immersive Environments: Developing Curriculum for Global Programs*. This study explores ways in which Universities can develop curriculum that will allow greater mobility between students at undergraduate level.

This raises interesting challenges concerning skills development and skills deficiencies. Professor Xue is leading China in research on teams and in particular regarding team learning, team cognition and team performance. Collaboration and communication is integral to effective teams. Previous work by Professor London whilst at Deakin University with her research fellow, Dr Vishal Singh on team cognition, team mental models and multi-disciplinary integration, specifically related to Building Information Modelling indicates that there is potential to build upon both centres past and current research in core competencies required in industrialised building, building information modelling and team leadership and practices for effective implementation.

There is also potential for the two research Centres to build upon the early curriculum mapping work currently being completed at RMIT. We often focus on 'skills development' from a trade perspective and yet there is a dearth of research in leadership skills for industrialised building and building information modelling at executive and middle management level. There is also a lack of research in tools to support decision making bringing these two areas together. The decision making framework completed in 2005 in the Collaborative Platforms Solutions project focussed on Model Servers for BIM only and did not include industrialised building. The coevolution of these two concepts is an opportunity for these two centres. There is alignment in management science approaches and a common language that would enable collaborative international studies and comparisons. This would be particularly useful if there is more trade flow between the two countries as well. There is certainly more flow between the two countries envisaged in the future in terms of tertiary student mobility. The focus on housing sector professionalization in the tertiary sector has been almost non-existent in Australia and this is an area of work that could be improved significantly through greater interaction between the two institutions.

3.1.3 FUTURE PROGRAM AND/OR PROJECTS

Specifically related to Integrated off site housing systems the following research areas were considered to be worthy of future exploration:

1. **Analysis of adoption patterns of emerging technology (BIM, Green, Off-site manufacturing) in Industrialised Building processes across China and Australia**
 - Baseline historical analysis in relation to policy events and documents and impact upon adoption
 - Analysis of perceptions including industry and end users stakeholders
 - Development of centralised data collection to profile, monitor and evaluate the sector
 - Cross country comparison of factors affecting adoption including market structure, firm conduct and government intervention
 - Sustainability evaluation of claims of increased sustainability of pre-fabricated buildings and the products
 - Urban Health of industrialised building on densely populated cities including pressure on transport infrastructure and improvements in regional air quality
 - Investigation of constructability issues in common and innovative industrialised building scenarios
 - Creation of indices and metrics to evaluate inputs (integration capability/technical skills/start up costs/ policy instruments) against outputs (efficiency/industry fragmentation/disputes/'smart' industry/urban health/OHS/sustainability)
2. **Examination of regulations, standards and specifications to support BIM adoption**
 - Development of an inventory of cross country comparison of similarities and differences in BIM and Industrialised building standards
 - Identification of current practices in each country
 - Evaluation of impact of disharmonisation of regulations on import and export
3. **Skills Development and Skills Deficiencies**
 - Identification of skills deficiencies and/or perceived deficiencies
 - Analysis of executive management leadership capability, knowledge, skills and competencies in Business Development and Financial Feasibility
 - Evaluation of professionalization of project management throughout the house project life cycle
 - Examination and creation of Building Information Modelling and Industrialised Building: Global curriculum for improved knowledge sharing and student mobility between the two countries
 - Appraisal of 'readiness' of the industry to embrace construction supply chain integration environments to support skills development

3.2 TSINGHUA UNIVERSITY

3.2.1 RESEARCH CAPABILITY

Professor Ma is Director of the Centre for Building Information Modelling. The BIM Centre is well funded from industry with a \$2M grant from a software vendor. Currently there are four major research projects being undertaken, including:

1. Application of IT in the management of construction firms
2. Collaborative system for multi-party in construction projects
3. BIM based collaborative system for IPD in building construction
4. Research on cost estimation of building construction projects based on BIM data of designs

3.2.2 AREAS FOR FURTHER RESEARCH

A significant difference between Australia and China is that off site manufacturing is termed industrialised building. 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. At this time Professor Ma wrote the government White Paper which supported the new 5 Year Agenda on Industrialised Building. Professor Ma does not undertake any research on industrialised building and only focusses on BIM and in particular commercialization of research to software development. There is potential for further research. It is important to note that these initial discussions indicated that there is generally a significant difference in research approaches between Professor London's research Centre members and Professor Ma's approach. The 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.



Figure 8 Professor Ma presenting on his research



Figure 9 Ray Thompson presenting on behalf of CSR



Figure 10 Adam Siegel presenting on behalf of Metricon



Figure 11 Ray Thompson presenting on innovation

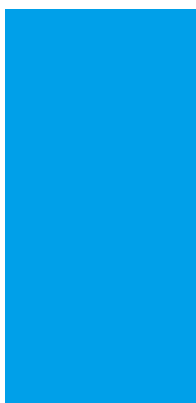


Figure 12 Adam Siegel presenting on sustainability action research project



Figure 13 Tsinghua Workshop



Figure 14 Collaborative BIM



Figure 15 Ongoing RMIT projects

Importantly there is another research group in Tsinghua University that RMIT could develop a significant collaboration and that is with the Disaster Prevention and Management Department. RMIT has capability in project management disaster management in the School of Property Construction and project Management within the Centre of Integrated Project Solutions.

3.2.3 FUTURE PROGRAM AND/OR PROJECTS

Specifically related to Integrated off site housing systems the following research areas were considered to be worthy of future exploration:

1. Collaborative Platforms Solutions

- Evidence based comparison of cost estimating impact on projects
- Evaluation of BIM based collaborative system for integrated project delivery targeted to in offsite housing systems including export and import standards
- Developing metrics for sustainability using industrialised building approaches
- Integrating project management legacy systems and Building Information Modelling

2. Examination of market incentives, regulations, standards and specifications to support BIM adoption

- Identification of current practices in each country
- Critique of market incentives vs government regulation approaches adopted to increase BIM adoption and industrialised building systems

3. Quality Assurance Systems

- Identification of IT Systems to support product flow
- Analysis of contribution BIM Harmonisation can make to Materials Stewardship

4 RESEARCH-INDUSTRY MISSION TO CHINA

Seven organisations were visited after the visits to the Universities. All the organisations were located in Beijing. We visited two research organisations, one product manufacturing company, one developer and three companies that manufacture modular housing. Table 2 summarises the organisations that were visited during the mission to China.

Organizations visited	Dates	Activities	Attendees	
			Australia	China
Case study 1 Research Institute	22 nd 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	22 nd Feb	Interview Visit factories	Prof. Kerry London ---RMIT Peng Zhang--- VAKIP Adam Siegel ---Metricon Ray Thompson--CSR	Deputy General Manager/ Chief Engineer
Case study 3 Manufacturing Modular housing	24 nd Feb	Interview Visit factories	Prof. Kerry London ---RMIT Peng Zhang--- VAKIP Adam Siegel ---Metricon Ray Thompson--CSR	Marketing Manager
Case study 4 Developer High rise apartments	24 nd Feb	Interview	Prof. Kerry London ---RMIT Peng Zhang--- VAKIP Adam Siegel ---Metricon Ray Thompson--CSR	Chief Engineer, Department of construction management
Case study 5 Manufacturing Modular housing Modular Temporary accommodation	25 nd Feb	Interview Visit factories	Prof. Kerry London ---RMIT Peng Zhang--- VAKIP Adam Siegel ---Metricon Ray Thompson--CSR	General Manager
Case study 6 Manufacturing Modular housing	25 nd Feb	Interview Visit factories	Prof. Kerry London ---RMIT Peng Zhang---VAKIP Adam Siegel ---Metricon Ray Thompson--CSR	Operation Manager
Case study 7 Research institute	26 nd Feb	Workshop	Prof. Kerry London ---RMIT Peng Zhang--- VAKIP Adam Siegel ---Metricon Ray Thompson--CSR	Division Chief of the MHURD of China, Associate Prof. at North China University of Technology, and Prof. at HIT

Table 3 Visits and interviews to organisations involved in industrialised building

4.1 CASE STUDY 1 RESEARCH INSTITUTE

Workshop attendance: Senior Engineer with 5 staff

4.1.1 ORGANISATION BACKGROUND

Case study 1 is a research institute which was founded in 1956 and it is one of the major units under the jurisdiction of the Beijing municipality. It is one of the key organisations in Beijing involved in scientific research on domestic construction engineering. In 2000 it was transformed into a high-tech enterprise.



Figure 16 Headquarters Research Institute

The Institute is mainly engaged in research and development on construction engineering applied technology. Its business scope includes research and development related to the following areas; structural engineering, foundations, civil engineering construction, mechanical and electrical machinery, engineering materials, building energy conservation, project examination and appraisal, construction supervision.

Over the last 50 years, the organisation has obtained more than 500 projects in scientific research including more than 150 major items and 100 patents of invention and utility models. During the past decade the Institute has carried out and completed more than 40 projects of scientific research separately at the levels of the state, the ministry and the municipality. The organisation was recognised by the Ministry of Construction as one of the units responsible for pushing forward and popularizing the 'Ten big new high-tech items' in China.

The Institute now has employees of 225 people, including professional and technical personnel numbering more than 170 people. This also includes two experts who have been recognised as providing 'outstanding contributions to Beijing', 12 professor-senior engineers, seven doctors and more than 60 masters.

The Institute is a science and technology enterprise in construction engineering which focusses on multi-disciplinary studies. Currently it involves two research centres: the Beijing Construction and Engineering Technology Research Centre and the Architectural Engineering Quality of Judicial Identification Centre; and also includes seven professional sub-institutes or sections including:

- Pre-stressed and Spatial Structure Technical Research Section,
- Pre-stressed Equipment Technical Research Section,
- Steel Bar Technical Research Section,
- Mechanical and Electrical Equipment Research Section,
- Engineering Material Research Section,
- Formwork Technology Research Section and
- Foundation Section.

It also includes: one capitalization unit: Beijing Construction Project Quality Detection Centre; three shareholding units: Beijing Building Technology Development Co. Ltd, Beijing Fangyuan Engineering Construction

Supervision Company, Pro-Bel (China) Company Ltd and one professional journal: "Building technology development".

The Institute at present has significant intellectual capital particularly in pre-stressed technology and products as well as for its new construction waterproofing technology and associated products. It also owns the large and comprehensive laboratories covering an area of several thousand square meters. Each section or sub-institute is modernized and equipped with design offices for its technology research and development work.



Figure 17 Project of case study 1

4.1.2 CHALLENGES

1. Lack of high skilled labour
2. Industrialised building increases the capital cost of buildings
3. Non technical research is needed to improve adoption

"We are training the low skilled labours and trying to make them to be the high skilled labours we need."

---Senior Engineer

4.1.3 INNOVATIONS

1. This institute has made significant achievements on new building technologies and materials, including:
 - A. Spatial Structure of Pre-stressed Technology and Climb Formwork Technology, which are used in the 2008 Olympic venues projects.
 - B. New building materials and waterproofing technology, i.e. AN4000 Polycarboxylate Superplasticizer.
 - C. New fire retardant building materials i.e. glass beads of insulation board, phenolic resin modified glass beads insulation board, phenolic resins insulation board, polyurethane insulation board and flexible decorative brick.
2. Building Information Modelling is in its earliest stages of introduction and is still considered quite an innovative technology however it will be an important part of the future of the industrialised building process.

4.1.4 UNIQUENESS/EXPERTISE

1. The research institute has significant intellectual capital in developing and testing new construction technology and materials.
2. Rigorous research studies to assist the government to change regulations and policies.

4.2 CASE STUDY 2

Interviewee's Role: Deputy General Manager/Chief Engineer

4.2.1 ORGANISATION BACKGROUND

This company was established in 1980 and has a history of 30 years. The company has a site area of 350,000m². At present, there are 1,000 workers and staff members and has an annual output value and sales income of nearly 1,000 million Chinese Yuan. The production facilities include 150 different sets of equipment. The production capacity is 150,000m³ for construction components and 12,000,000m³ for ready-mixed concrete.

The main products of this company cover civil engineering concrete products which are predominantly prefabricated. The main products include: decorative external concrete panel, fair-faced precast concrete stands, reinforced concrete shield tunnel segment, post tensioned concrete bridge elements, industrialised residential building components and high performance ready-mixed concrete. About 50,000m² prefabricated concrete products are manufactured for the industrialised housing sector and the revenue is about 150 million Chinese Yuan per year.



Figure 18 Prefabricated concrete structural products at case study factory yard



Figure 19 Prefabricated concrete structural products at case study factory yard

This company has its own research centre which provides research and development for new products and projects as well as technical advisory services. The centre has developed a series of high-tech products and of which it owns the intellectual property rights. The company has been involved in a number of high quality innovative prefabricated products. For example, the fair-faced concrete stands in the National Stadium (the Bird's Nest) and the fair-faced concrete cladding panels in Wuhan Qintai Cultural Arts Centre. This company typically supplies the concrete components construction companies and developers.

4.2.2 CHALLENGES

1. Business issues with construction companies and developers, including price, payment defaults, schedule changes, disputes on quality and service.
2. Delivery delays by the transportation companies
3. Lack of awareness of Building Information Modelling; and varied adoption patterns in customers and installation contractors; varied quality/level and unreliable level of detail in models
4. Lack of trained labourers
5. Lack of construction management skills in relation to BIM
6. High variability in regarding to project design and changes during project implementation
7. Profitability is decreasing because of the higher competition.

“We have used the BIM technology in the design stage of the big residential and infrastructure projects. However, it is only the beginning stage for us to adopt BIM.”

---Deputy General Manager

4.2.3 INNOVATIONS

1. Company is a leader in Building Information Modelling; although they are in the early stages BIM is not used extensively across the industry and only a little on residential and infrastructure projects in the design stages.
2. The scientific and technological outcomes with independent intellectual property rights include:
 - A. 3 creation patents,
 - B. 6 utility model patents,
 - C. 20 proprietary technologies
 - D. 5 award-winning scientific and technological achievements

4.2.4 UNIQUENESS/EXPERTISE

1. This company is the leading company in Precast/Prefabricated concrete components and ready-mixed concrete in China.
2. The company has its own designers and research centre.

4.3 CASE STUDY 3

Interviewee's Role: Marketing Manager

4.3.1 ORGANISATION BACKGROUND

This company is a manufacturer of modular houses, steel framed buildings and coloured steel products (sandwich panels/structural sections, fibrous materials). They provide services in relation to consulting, design, production and on site construction. The company exports modular houses, temporary accommodation for construction sites and is a contractor for various steel products.

Specifically the following products are within the business scope of the company; modular houses, steel framed buildings, colour steel sandwich panels (polystyrene, polyurethane, rock wool, glass fibre, and phenol aldehyde), coloured steel contour plates, C/Z/H-shaped steels and project complementary products. The types of projects include temporary construction accommodation, mining sites, military projects, residential buildings, industrial plants, gymnasiums, exhibition halls and temporary accommodation for disaster rescue and relief work.



Figure 20 Example of a Prefabricated house product from case study 3

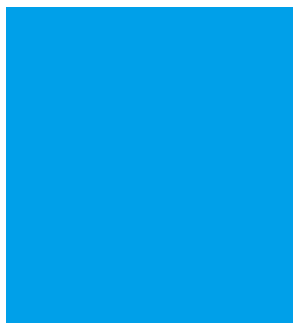


Figure 21 Manufacturing facilities of case study 3

The company produces 1.6 million square meters of modular houses per annum, 50,000 tons of steel structures and 3 million square meters of coloured steel contour plates per annum. The company exports to more than 70 countries and regions including the USA, Australia, New Zealand, Singapore, Bengal, Angola, Venezuela, Mozambique etc. The company produced 450,000m² panels and 150,000m² modular houses/ prefabricated houses in 2013.

This company is one of the 6 member companies in the Jing Hua Tong Company Group (JHT). The total revenue of JHT is about 700 million Chinese Yuan in 2013. It is a middle sized company in this sector.

4.3.2 CHALLENGES

1. When exporting one of the greatest challenges is gaining certification/ license from the foreign countries' government.
2. Transportation is key to the exporting of products and problems, i.e. delays can impact the servicing of contracts and increase lead times and affect profitability on projects and ultimately company reliability and credibility.
3. Product upgrading is very slow.
4. Profitability is decreasing because of the increase in competition.

"We couldn't find the information about how to get the certification/ license from the foreign counties' government for our product to export to these countries."

---Marketing Manager

4.3.3 INNOVATIONS

1. Transferring from manufacturing components (i.e. Panels) of the house to the whole completed prefabricated house
2. Pre-assembled system to check if the parts are matched or not before installation
3. Company trains labourers on site to install and sends supervisors to overseas projects to ensure quality control.
4. Company imports advanced technology and machinery from developed countries, i.e. Italy, Spain.
5. Company adapts and modifies the imported machinery and equipment to suit their actual needs.

4.3.4 UNIQUENESS/EXPERTISE

1. Comprehensive export business
2. Prefabricated modular housing
3. Significant disaster contracts

4.4 CASE STUDY 4

Interviewee's Role: Chief Engineer, Department of Construction Management

4.4.1 ORGANISATION BACKGROUND

Founded in 1984, this company began to engage in real estate in 1988, and was the second listed company on the Shenzhen Stock Exchange in 1991. Over the last two decades, this company has become the largest residential developer in China, whose business covers 63 large and medium-sized cities in the Pearl River Delta region, the Yangtze River Delta region and the Bohai Economic Rim, as well as central and western parts of China. In the past three years, the average number of homes sold annually has exceeded 60,000. In 2011, sold floor space totalled 10.75 million square meters and sales reached RMB 121.5 billion. In 2013, sales exceeded RMB 170 billion, and were deemed the largest real estate company worldwide. There are more than 27,000 employees working in this company.



Figure 22 Case study 4 office

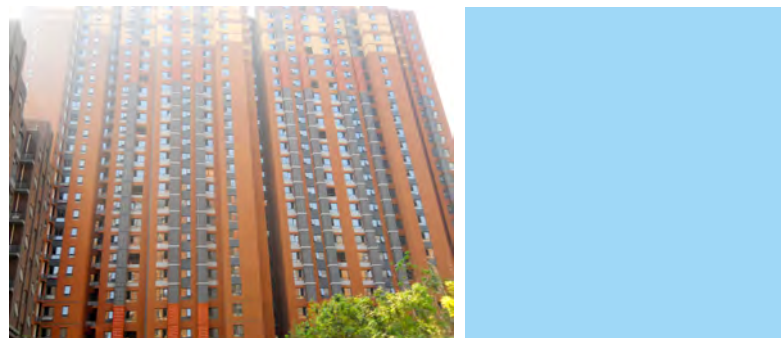


Figure 23 Case study 4 project multiunit high rise apartment building

In 2007, this company's Architecture Research Centre was approved as one of the National Research Centres for housing industrialization by the Ministry of Housing and Urban-Rural Development. In 2011, this company started to build 2.72 million square meters of prefabricated buildings, which is 2.55 times as much as 2010. In 2013, this company's new industrialised building projects reached at 6.9807 million m², which is 42.37% of all our projects.

This company doesn't have its own design department. All the design tasks are out sourced and specifically the company tends to partner with other large Design Institutes in China.

4.4.2 CHALLENGES

1. No support in the beginning of developing and adopting the new technology (BIM, Prefab, Industrialized Building, etc.)
2. No policy or regulation in regarding to new technology and new standards
3. Push the government to change standards and regulations
4. Cost on generating new technology and feasibility studies
5. Lack of technologies
6. Lack of trained labours/traders
7. Suppliers don't know the new technology and don't know how to make the components.
8. The designers don't know how to design this kind of building.
9. It is difficult in the design stage to make sure all the parts are matched.
10. The size of the parts can vary and it has been difficult to manufacture effectively.
11. Increased the cost of building. The cost would be increased by 100-500 RMB per m².

4.4.3 INNOVATIONS

1. Improved management skills and quality of products by using industrialized building technology
2. Better quality control by using industrialized building technology and reduction in the errors from 'cm' level to 'mm' level
3. Company is the leader in prefabrication and industrialised building processes
4. Design rationalisation and constructability through product standardization
5. Leader in Building Information Modelling; although still in its infancy

“By using industrialized building technology, the errors of our product have reduced from ‘cm’ level to ‘mm’ level.”

---Chief Engineer

4.4.4 UNIQUENESS/EXPERTISE

1. Market leader in real estate sector
2. Residential developer - integrated resources using partner organizations
3. Explore and implement new construction technology
4. Assist the government to change regulations and policies
5. Lead the industry in identifying the future research directions

4.5 CASE STUDY 5

Interviewee's Role: General Manager

4.5.1 ORGANISATION BACKGROUND

This company was established in 2009, and is a manufacturer of modular houses. The company has 20,000 square meters of production facilities located in the outer area of Beijing and includes various workshops including; forming, welding, painting, carpentry and assembly. This company is attempting to specialize in the production of European standards' modular housing. There are 45 employees in this company currently.



Figure 24 Example of case study 5 modular housing product

This company develops and manages new container housing and promotes the standardization and modularization of the temporary building. The company promotes energy saving and environmental design, quick installation and customised optional design combinations. The housing products are widely used as temporary and permanent buildings in North America, South America, Australia, Europe, Southeast Asia and the Middle East. 640 container housing units were sold in 2013 and the overall revenue of this company was 8 million Chinese Yuan.



Figure 25 Typical modular housing product



Figure 26 Case study 5 modular temporary office accommodation

4.5.2 CHALLENGES

1. Identification and meeting foreign countries' regulations, standards and requirements.



Figure 27 Case study 5 factory facilities 'flat pack' type production

4.5.3 INNOVATIONS

1. Changing the focus from international market to both international and domestic market.

“The [Chinese] domestic market is increasing gradually. We are going to focus on both international and domestic market.”

---General Manager

4.5.4 UNIQUENESS/EXPERTISE

1. Ability to be flexible and capability to respond to temporary construction sites and disaster project needs.

4.6 CASE STUDY 6

Interviewee's Role: Operation Manager

4.6.1 ORGANISATION BACKGROUND

This company was established by Beijing New Building Materials Public Limited Company with two Japanese Top500 companies: Nippon Steel Company Limited and Toyota Housing Corporation; in December Of 2002 with a total investment of RMB 200 million. The company introduced advanced light gauge steel stud structure building technologies and production line for manufacturing. By using these advanced technologies and the production line, this company can design, construct and install light gauge steel stud structure building in standardized, fine and customized ways.

The company's light gauge steel stud structure for housing is an innovation in the Chinese construction industry. The majority of housing in China is high rise multi unit apartments tower blocks using concrete as the main structural component. Low rise residential such as the houses produced by this company is new. The typical method of construction of Chinese housing is multi unit apartments constructed from concrete structural frames and clad in precast concrete. The approach taken by this company is aligned to the residential industry policy of saving four kinds of energy and being environment-friendly. The standards of construction by this company were authorized by a state residential industrialization based by the Ministry of Construction (the current Ministry of Housing and Urban-Rural Construction) at the end of 2002. In 2013, more than 20 types of detached house were manufactured and sold by this company, and the size ranged between 90m² to 500m². 200 houses were manufactured in 2013. Most of these houses were for the domestic market.



Figure 28 Case study 6 typical modular housing product



Figure 29 Case study 6 typical modular housing product

For decades, this company has undertaken many domestic and overseas large-scale projects, the product and service have covered over 10 provinces. The company has also undertaken post-disaster reconstruction tasks and provided temporary housing on many projects. Along with the further implementation of the national strategy of 'Out-going', the company has completed dozens of projects in international market in North America, East Europe, Middle East, South Asian, South America, South Pacific Islands and African countries. The production capacity in 2013 was approximately 3,000 to 4,000 X 200m² standard houses.

This company has its own design department with 10-12 employees. There are 21 to 22 employees working in this company's manufacturing facilities now.



Figure 30 Case study 6 factory: 'flat pack' modular housing walls



Figure 31 Case study 6 'flat pack' wall framing construction

4.6.2 CHALLENGES

1. Industry Policy in regarding to land use for detached housing is not conducive to this market
2. Communication with clients about design including changes of design and changes in scope
3. Errors on construction drawings
4. Lack of communication between design and construction units

“Currently, because of the land use polices of China, detached houses do not have many market opportunities.”

---General Manager

4.6.3 INNOVATIONS

1. New products by using new material and advanced technology, i.e. light gauge steel stud structure for housing and OSB board. As China's Oriented Strand Board (OSB) market pioneer, this company has been committed to the promotion and application of Oriented Strand Board (OSB) in China and has owned the brand. Oriented strand board (OSB) is a material with high mechanical properties that make it particularly suitable for load-bearing applications in construction. OSB as the structural board has the characteristics of pressure-resistance, bending-resistance to fit the light-steel villa. The most common uses are as sheathing in walls, flooring, and roof decking. OSB also sees some use in furniture production. This company's OSB board is an Environment-friendly product and its release of Formaldehyde is in accordance with the European E1 standards.
2. Imported advanced machinery and equipment from developed countries.

4.6.4 UNIQUENESS/EXPERTISE

1. Steel structure prefabricated building
2. Aesthetic design
3. Detached housing
4. Integrated design, construction and production

4.7 CASE STUDY 7

Workshops with Division Chief of the Science Technology and Industrialisation Development Centre, Ministry of Housing and Urban-Rural Development, China



4.7.1 CHALLENGES

1. No policy or regulation in regarding to BIM in housing sector. How to match/integrate the different standards/codes is a big issue. The Chinese government is going to build a national BIM platform. The interface of the platform needs to be standardized.
2. Industrialised building increases the initial capital cost of the buildings. It was 500-600 RMB/m² extra 20 years ago. The extra cost has come down to 100 RMB/m² since the industrialised building policy was first promulgated by the government.
3. Some companies do not realize the potential benefits of the industrialised building, i.e. reducing labour cost, increasing efficiency and increasing safety on site.
4. Lack of trained labourers
5. False propaganda of some companies. For example, one company for advertising purposes announced that they constructed a steel high rise building in Shanghai in an extremely fast timeframe. However, the technology is still immature and not ready. This building does not exist. It is hype and the comment was that was '(is) a national joke'.

“In order to facilitate the development the industrialised building, the Chinese government provides policy support, labour trained/education support and research funds to the industry and institute.”

---Division Chief

4.7.2 INNOVATIONS

1. Fund research projects to develop and improve the policies and standards in relation to industrialised building
2. Government provide incentives for construction companies which adopts off site manufacturing/ industrialised building technology or products.

APPENDICE NATIONAL BENEFITS AND SUCCESS INDICATORS

Economic benefit

Measure	Success Indicator
<p>The national economic benefit will be improved housing affordability as a result of increased participation by the industry in OSM. OSM will require integrated supply chains and improved knowledge. Through the proposed mission, we will identify barriers and enablers to higher levels of OSM and improve transfer of knowledge related to products, systems and technologies between the two countries.</p> <p>The improved knowledge based will be measured by increased research activity. The first step though is to initiate a joint research program. The benefits can also be measured in improved knowledge in the industrial sectors, government sector and the international research community. Activities that will contribute to the knowledge base include:</p> <ul style="list-style-type: none"> - Report on current state of OSM in Australia, Lessons Learnt, and OSM Research Roadmap - Public seminar in Australia to market leaders to raise awareness - Workshop with relevant Australian government stakeholder to address structural barriers 	<p>For the measure of improved knowledge base in industrial sectors, government sector and international research community there are both short and long term indicators of success:</p> <p>Short term:</p> <ul style="list-style-type: none"> - Research Program is created and a Roadmap is developed for the knowledge cluster - Research publication analysing the policy initiatives required to drive the priority themes of the Australian national Built Environment Industry Innovation Council in relation to: * a culture of innovation; * novel integrated design and delivery solutions; * strategic procurement through the value chain; * future vision of construction knowledge roles/ skills; and * use of Building Information Models - Identify barriers and enablers for OSM activities <p>Long term:</p> <ul style="list-style-type: none"> - Transfer knowledge between OSM sectors in both countries - Long-term benefit: increased OSM implementation informed by knowledge cluster - Long-term benefit: develop novel integration systems for cost effective OSM implementation

Environmental benefit

Measure	Success Indicator
<p>Off-site manufacturing will have environmental benefit as it an answer to the construction industry problems related to waste reduction on sites; and cleaner and low carbon emission activities during construction process.</p>	<p>Better understanding of how to achieve environmental sustainability through knowledge transfer during the site visits as described in Activity 2. The knowledge sharing among partners from both countries would bring mutual benefit to all the partners involved. Partners from both countries will plan joint research-related programs to include research and research-driven innovation for achieving environmental sustainability through off-site manufacturing within the construction industry.</p> <p>The following are indicators of success:</p> <ul style="list-style-type: none"> - Research Program is created (research projects with partners looking at effective waste reduction strategies through OSM) - Transfer Knowledge between OSM sectors in both countries on environment related issues - Long-term benefit: reduce waste to land fill - Long-term benefit: develop research collaboration with industry partners to create novel integration systems for OSM implementation resulting into cleaner and low carbon footprint construction site.

Social Benefit

Measure	Success Indicator
<p>Off-site manufacturing of components can address the construction industry problems related to health and safety issues during on-site construction process.</p>	<p>Following are indicators of success:</p> <ul style="list-style-type: none"> - Research Program is created including research projects with industry partners to look at OSM implementation and Occupational Health and Safety (OH&S) issues - Transfer Knowledge between both countries regarding OH&S through OSM Industry change - Long-term benefit: reduction in number of accidents during on-site construction activities - Long-term benefit: increased OSM implementation informed by knowledge cluster

Table 1 Summary of Economic, Environmental and Social National Benefits



<http://www.industrialisedbuilding.com>



Centre for Integrated Project Solutions

360 Swanston St

Building 8, Level 8

School of Property, Construction and Project Management

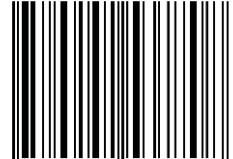
RMIT University

Director: Professor Kerry London

Contact: Kerry.London@rmit.edu.au

Mob: + 61(0)428611647

ISBN 978-0-9925377-0-8



9 780992 537708 >