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CPSISC
Construction & Property Services Industry Skills Council

Job Skills in Prefabricated Construction

Dr Philip Alviano

2014 International Building and Construction Fellowship

An ISS Institute Fellowship sponsored by

The Construction and Property Services Industry Skills Council (CPSISC)

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i. EXECUTIVE SUMMARY

Prefabrication in construction takes in a variety of systems. These range from tilt concrete panel slab or Cross Laminated Timber (CLT) panel systems, pre made timber frames and roof trusses, Structural Insulated Panels (SIPs) through to prefabricated pods fitted out off site and dropped directly into place. In this case plumbing, tiles, joinery and appliances are fitted offsite. The move to prefabrication means that more of the construction process can take place offsite in a manufacturing plant environment. This produces a more controlled environment where the use of Lean Manufacturing and Building Information Management (BIM) can result in efficiency gains. There are also environmental benefits which include waste reduction, materials efficiency and tighter, better insulated buildings.

In Scandinavian countries approximately 50% of residential housing is largely manufactured off site and in Finland it is 74%. In Australia only 3% of residential buildings are prefabricated. This number is growing and there is an ambition to achieve 10% of the residential market by 2020 (Newman and Green 2014). This will require an increase in workers with the hybrid skills from both process manufacturing and construction.

This Fellowship aimed to engage with the well developed prefabrication building industry in Germany to identify job roles and skills sets of the workforce. Training programs and pathways were also identified. This was then converted to an Australian context by the completion of a skills gap analysis to identify the type of person and qualification required by the prefabricated construction industry in Australia.

The type of person and qualification required by the prefabricated construction industry requires a blend of manufacturing and construction skill sets. This will require existing workers in manufacturing to increase their knowledge of construction processes, skills and knowledge; and those in construction to do the opposite. The demands of their actual job role will determine just how much extra knowledge they will need. New people looking to enter the prefabricated construction industry may look towards blended qualifications that encompass units of competency from both the manufacturing and construction packages.

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ii. ABBREVIATIONS/ACRONYMS

BIM	Building Information Modelling
CAD	Computer aided design
CIPSISC	Constructions and Property Services Industry Skills Council
CLT	Cross Laminated Timber
CNC	Computer Numerical Control
CPSISC	Construction and Property Services Industry Skills Council
DENA	Deutsche Energie-Agentur GmbH – the German Energy Agency, is the centre of expertise for energy efficiency, and renewable energies
DET	Department of Education and Training, Victorian Government
EEoz	(or E-Oz) energy Skills Australia
KfW Bank	A government owned bank that authorises reduced loans from other banks where houses meet certain energy efficiency levels which are less than standard homes
MSA	Manufacturing Skills Australia Industry Skills Council
RTO	Registered Training Organisation
SIPs	Structural Insulated Panels
TAFE	Technical and Further Education
VET	Vocational Education and Training

iii. DEFINITIONS

Fermacell

Is a plaster board replacement made from gypsum and recycled paper fibres. These two natural raw materials are mixed with water, without any other binders being added.

Gluelam

Short for glued laminated timber. It is an engineered wood product manufactured by gluing together pieces of timber, known as laminates.

Lean Manufacturing

A systematic method for the elimination of waste within a manufacturing system. The waste is not only in the form of materials used, but also waste created through unevenness in workloads or other inefficiencies in the production process.

Low e Coating

Low-e is standard clear glass that has a special coating on one surface of the glass. Low-e refers to low emissivity and this describes the capacity of a surface to radiate heat. Emissivity is measured across a scale from 0 to 1 with 1 representing the highest emissivity.

Passive House

The term passive house (Passivhaus in German) refers to a rigorous, voluntary standard for energy efficiency in a building, reducing its ecological footprint.

1. ACKNOWLEDGEMENTS

Dr Philip Alviano would like to thank the following individuals and organisations that have generously given of their time and their expertise to assist, advise and guide him through this Fellowship program.

Awarding Body – International Specialised Skills Institute (ISS Institute)

The International Specialised Skills Institute (ISS Institute) is an independent, national organisation. In 2015 it is celebrating twenty-five (25) years working with Australian governments, industry education institutions and individuals to enable them to gain enhanced skills, knowledge and experience in traditional trades, professions and leading edge technologies.

At the heart of the ISS Institute are our individual Fellows. Under the Overseas Applied Research Fellowship Program the Fellows travel overseas. Upon their return, they are required to pass on what they have learnt by:

- Preparing a detailed report for distribution to government departments, industry and educational institutions
- Recommending improvements to accredited educational courses
- Delivering training activities including workshops, conferences and forums.

Over 350 Australians have received Fellowships, across many industry sectors. In addition, recognised experts from overseas conduct training activities and events. To date, 30 leaders in their field have shared their expertise in Australia.

According to Skills Australia's 'Australian Workforce Futures: A National Workforce Development Strategy 2010'.

> *Australia requires a highly skilled population to maintain and improve our economic position in the face of increasing global competition, and to have the skills to adapt to the introduction of new technology and rapid change. International and Australian research indicates we need a deeper level of skills than currently exists in the Australian labour market to lift productivity. We need a workforce in which more people have skills and knowledge, but also multiple and higher level skills and qualifications. Deepening skills and knowledge across all occupations is crucial to achieving long-term productivity growth. It also reflects the recent trend for jobs to become more complex and the consequent increased demand for higher-level skills. This trend is projected to continue regardless of whether we experience strong or weak economic growth in the future. Future environmental challenges will also create demand for more sustainability related skills and knowledge across a range of industries and occupations.*

In this context, the ISS Institute works with our Fellows, industry and government to identify specific skills and knowledge in Australia that require enhancing, where accredited courses are not available through Australian higher education institutions or other Registered Training Organisations. The Fellows' overseas experience sees them broadening and deepening their own professional knowledge, which they then share with their peers, industry and government upon their return. This is the focus of the ISS Institute's work.

For further information on our Fellows and our work see http://www.issinstitute.org.au.

The Fellow also thanks the CEO (Bella Irlicht AO) and staff (Ken Greenhill and Paul Sumner) of ISS Institute for their assistance in planning and development of the Fellowship and completion of this report.

Governance and Management:

1. ACKNOWLEDGEMENTS

Fellowship Sponsor

The Construction and Property Services Industry Skills Council (CPSISC) is the Industry Skills Council for the Building and Construction Industry and related industries of Australia. The Fellow thanks them for providing funding support for this Fellowship.

Supporters

The following Australian mentors provided Fellowship support:

- Damien Crough formerly with Hickory Group, Founding Director, prefabAUS and Managing Director, Advanced Offsite Group.
- Grant Daly, Consultant Change Manager, Building and Construction Industry Training Organisation. Formerly Director of Policy and Research, Construction and Property Services Industry Skills Council (CPSISC)
- Julie-Anne Sheppard, Manager Strategic Projects, Master Builders Association of Victoria

Additional Australian Contributors:

- Rob de Brincat, Business Development Manager at XLam Australia Pty Ltd
- Jill Johnson, OMC Media
- Kase Jong, Estimating Manager, Australand (now known as Frasers Property)
- George Konstandakos, General Manager at Timber Building Systems, Plan Consulting
- Adrian Robertson, Timber Truss

German Contributors:

- Hermann Fink, Manager, Fink Haus,
- Johannes Fischer-Zernin, Product Manager, BeA Group
- Herbert Giptner, Building Services, City of Munich
- Professor Rainer Grohman, Wood Technology, Rosenheim University of Applied Sciences
- Christian Gscheidmeier, Project Manager, Baufrtiz
- Reinhardt Kleinoder, Department of Health and Environment - City of Munich.
- Thomas Lill, Director of International Sales, BeA Group
- Hansbert Ott, Managing Director, Weinmann,
- Jocham Renner, Company Manager, Schworer Haus
- Silke Thomas, Customer Relations Consultant, HUF Haus
- Rainer Walser, Designer, Franz Walser Holzbau
- Steffen Webber, Global Technical Sales, Hundegger
- Torsten Windmuller, International Projects, Holzbau Baden-Württemberg Bildungszentrum
- Christoph Windscheif, Head of Marketing, German Prefabricated Building Manufacturers Association

Australian Organisations Impacted by Fellowship Findings:

Government

- Federal, State and Territory Government
  - » Building and Plumbing Commissions (each state and territory)
  - » Department of Education and Training
  - » Department Industry, Innovation, Science, Research and Tertiary Education
    - » Built Environment Industry Innovation Council
  - » Department of Housing
  - » Development Agencies (e.g. Places Victoria)
  - » Local Government including Planning and Environment Departments

Education and Training

- Industry continuing professional development programs (e.g. Engineers Australia,
- Industry Skills Councils (e.g. CPSISC, EEoz, MSA)
- Vocational Education and Training (VET)
- Registered Training Organisations (RTOs, private training providers and TAFEs)
- State and territory training authorities (e.g. TAFE NSW, Higher Education and Skills Group, Skills Victoria, Department of Education and Communities NSW)
- Universities Research Centres e.g. (Cooperative Research Centre for the Built Environment)

Industry Practitioners

- Inspectors, surveyors
- Builders
- Construction and project managers
- Specialty professionals and tradespeople (e.g. Carpenters, plumbers, electricians, insulation installers, designers, engineers, estimators, quantity surveyors)
- Mortgage/lending brokers
- Property developers
- Real estate brokers
- Property valuers

Industry & Professional Associations

- Large volume builders (e.g. Henley Homes, Burbank Homes, Dennis Family Homes, National Builders)
- Manufacturers (e.g. CSR, Boral)
- Suppliers (e.g. Bunnings, Mitre10, Masters)
- Building Associations (e.g. HIA, MBA, MPMSAA)

1. ACKNOWLEDGEMENTS

- Standards Australia
- Air Conditioning and Mechanical Contractors' Association
- Australian Institute of Quantity Surveyors
- Professional Associations (e.g. Australian Institute of Architects, Building Designers Association of Australia)
- Unions (e.g. Construction Forestry Mining and Energy Union, Communications Electrical Plumbing Union)

Community

- Home owners/consumers
- Owner builders

2. ABOUT THE FELLOW

Name

Dr Philip Alviano

Employment

Sustainable Building Advisor, Master Builders Association of Victoria

Qualifications

- Doctor of Philosophy, University of Melbourne, 2000
- Master of Environmental Science, Monash University, 1993
- Bachelor of Education (Environmental Science), Melbourne College of Advanced Education, 1988

Short Biography

Dr Alviano has been employed as the Sustainable Building Advisor at Master Builders Victoria for the past eleven years. As well as providing advice to industry as required he is responsible for Sustainable Building training programs in Victoria. His extensive experience in education and training has informed the development of the unique nationally recognised construction Certificate IV qualification in environmental management and the national roll out of the accredited Master Builder Green Living program.

He has worked on building and construction related projects for the last 13 years, including working as one of the environmental consultants on the Victoria to Tasmania natural gas pipeline link. His has also spent time working for the Environment Protection Authority Victoria, Melbourne Water and local government.

Dr Alviano has a PhD in Ecology and Land Management, a Masters Degree in Environmental Science and a background in education.

3. AIM OF THE FELLOWSHIP PROGRAM

Unlike the rest of the world, prefabrication is still a small component of the overall market in Australia, but expected to grow sharply in the next 10 years (Newman and Green 2014). The move to prefabrication means that more of the construction process can take place offsite in a manufacturing plant environment. This produces a more controlled environment where the use of Lean Manufacturing and Building information modeling (BIM) can result in efficiency gains. There are also environmental benefits which include waste reduction, materials efficiency and tighter, better insulated buildings. This will require an increase in workers with the hybrid skills from both process manufacturing and construction. Goodier and Gibb (2007) found that an increase in prefabrication in the United Kingdom was being held back by a lack of available multi-skilled labour to work in the offsite factories.

The specific research aims of the Fellowship were to:

- Investigate the level of knowledge and qualifications that may be required for a manufacturing workforce involved in the assembly of prefabricated buildings.
- Determine the new skills required for a manufacturing workforce involved in the assembly of prefabricated buildings.
- Development of a skill set based around a set of competencies that will be required for a manufacturing workforce involved in the assembly of prefabricated buildings.

The strategies carried out to meet the aims of the Fellowship were:

- Conducted site visits to a number of well developed prefabricated construction facilities in Germany to document the systems involved in the production process which may be applicable to an Australian context.
- Documented job roles involved in the production process both on and offsite and how they may be applied in an Australian context.
- Documented skill sets involved in the production process both on and offsite.
- Converted the skills sets identified into a series of competencies relating to the Australian Vocational, Education and Training System.
- Developed competencies in conjunction with industry partners to bridge the skills gaps and develop career pathways.

4. THE AUSTRALIAN CONTEXT

Prefabrication in construction takes in a variety of systems. These range from tilt concrete panel slab or cross laminated timber (CLT) panel systems, pre-made timber frames and roof trusses, structural insulated panels (SIPs) through to prefabricated pods fitted out off site and dropped directly into place. In this case plumbing, tiles, joinery and appliances are fitted offsite.

In Scandinavian countries approximately 50% of residential housing is largely manufactured off site and in Finland it is 74%. The prefabrication industry in Australia is in its infancy with only 3% of residential buildings prefabricated. This number is growing and there is an ambition to achieve 10% of the residential market by 2020 (Newman and Green, 2014). The increase in demand is expected to be driven by increasing construction costs and the need to reduce costs by looking for the increased efficiencies gained through prefabrication. This is especially relevant in the mid rise apartment and townhouse market.

This expected increase in the Australian manufacture of prefabricated buildings is expected to occur in conjunction with a downturn in the car manufacturing sector and a likely major loss of jobs. Thus, there is an opportunity for these skilled car manufacturing personnel to transfer their skill sets to new technologies and industries. The fellowship aimed to engage with the prefabrication building industry to identify skills set deficiencies as well as the transferability of skills between prefabricated building projects and other manufacturing environments.

This will require the type of person and qualification that has a blend of manufacturing and construction skill sets. Existing workers in manufacturing will need to increase their knowledge of construction processes, skills and knowledge and those in construction to do the opposite. Just how much extra knowledge they will need will depend on their job role. New people looking to enter the prefabricated construction industry may look towards blended qualifications that encompass units of competency from both the manufacturing and construction packages. There will also be a requirement to determine what happens with the current system of apprenticeship training and how this will relate to the prefabricated construction environment.

prefabAUS

During an Australian Research Council Linkage Grant Future Proofing Schools Round Table Session of June 2012, there was seen to be a need for a Peak industry body to support and drive the increase in prefabricated housing in Australia. ‘prefabAUS’ came into existence in 2013 to support collaboration, innovation and quality information sharing.

Following this initiative, ‘prefabAUS’ works with manufacturers, architects, building designers, engineers, and other construction professionals, affiliated industry associations, research bodies, client groups, government agencies, and regulatory bodies to advance Australian building prefabrication. It’s stated goals are to:

- Educate a wide audience about the benefits of modern building prefabrication
- Act as a portal for quality information about Australian building prefabrication
- Explore and address barriers to the uptake of building prefabrication
- Encourage research and development programs across the industry.

In December 2014 the Victorian Department of State Development, Business and Innovation convened an industry round table discussion group which is now investigating the industry’s potential and barriers impeding its growth.

4. THE AUSTRALIAN CONTEXT

Benefits of Prefabrication

The move to prefabrication means that more of the construction process can take place offsite in a manufacturing plant environment. This produces a more controlled environment where the use of Lean Manufacturing and BIM can result in efficiency gains (Howe 2015, Blismas and Wakefield 2009). There are also environmental benefits which include waste reduction, materials efficiency and tighter, better insulated buildings. The increased efficiencies will largely come from the reduction of waste in all its forms brought about by the introduction of lean manufacturing techniques possible in a prefabricated construction environment. Waste in construction includes:

- **Waiting Time** - when people, equipment or product wait for other processes or workers to finish an up-stream activity. It is related to the idle time caused by lack of synchronization and leveling of material flows, and lack of pace of work by different groups or equipment. Poor coordination between the trades will also cause this waste.
- **Motion Waste** – this occurs when extra steps are taken by people to accommodate inefficient process layouts, defects, reprocessing, over production or excess inventory.
- **Processing and Over-Processing waste** - Processing is related to the nature of the processing activity, which could be avoided by changing the construction technology. For instance a percentage of mortar is usually wasted when a ceiling is being plastered (Sowards, 2005). The term over processing generally refers to unnecessary steps in operations, such as reprocessing, double handling, added communication and double-checking which adds no value to the product or service.
- **Over production waste** - In construction, over production is observed when shop workers fabricate materials too early or when materials are stockpiled either in a warehouse or at the jobsite (Sowards, 2005).
- **Transportation waste** – occurs when there is unnecessary motion or movement of products or materials that are not used immediately in the construction; are transported from one jobsite to another or back to the supplier. The materials are also exposed to handling damages (Sowards, 2005).
- **Correction or defect waste** - Corrections and defects are works not done correctly the first time, which must be repaired, sorted, re-made or redone.
- **Confusion** - Caused when there is missing or a lack of clarity. This causes uncertainty when making decisions, reducing smooth work flow.

These benefits derived from prefabricated construction will require a skilled and trained workforce that has the manufacturing knowledge and trade skills to deliver in a timely and effective manner.

SWOT Analysis of the improved job skills identification, training and career pathways for the prefabricated construction industry.

Strengths

- A well developed training system already exists in Australia.
- Units of Competency already exist that could be used to cover skills deficiencies or modified to meet the needs of a prefabricated construction industry.
- Targeted training programs for the hybrid construction and manufacturing skills of the prefabricated construction workforce.
- Recognition from industry and government that growing the prefabricated construction industry is extremely important to both the manufacturing and construction industry.
- A better trained and motivated workforce able to work more efficiently and productively.
- Improved quality outcomes from a better trained workforce.

Weaknesses

- The poor image of prefabricated housing in Australia by consumers.
- The lack of uptake from the prefabrication industry of new training packages.

Opportunities

- New jobs and career pathways for an already skilled manufacturing workforce.
- New jobs to replace those lost from the vehicle manufacturing industry in Australia
- Improvements to the energy efficiency performance of new prefabricated houses and a related fall in energy use and greenhouse gas emissions.
- Alternative career pathways for those working in the construction industry.
- Alternative apprenticeship training pathways.

Threats

- The lack of consumer acceptance of prefabricated housing in Australia.
- The need to determine where these workers sit in the award system and the conflict that may arise from this.
- Unions and the conflict arising from the inability to define these workers as either manufacturing or construction.

5. IDENTIFYING THE SKILLS AND KNOWLEDGE ENHANCEMENTS REQUIRED

There are examples of areas in Australian industries where there are weaknesses in innovation, skills, knowledge, experience, policies and/or formal organisational structures to support the ongoing successful development and recognition of individuals and the particular sector.

The focus of all ISS Institute Fellowships is on applied research and investigation overseas by Australians. The main objective is to enable enhancement and improvement in skills and practice not currently available or implemented in Australia and the subsequent dissemination and sharing of those skills and recommendations throughout the relevant Australian industry, education, government bodies and the community.

The areas of applied research for this Fellowship as identified for the Building and Construction industry are therefore defined as follows:

1. Investigate and document production methods for offsite prefabricated construction including those applicable to onsite assembly and other new processes and innovation in the industry overseas.

- Identify and assess the systems involved in the production process through site visits, interviews.
- Interpret the systems to see if they are applicable to an Australian context and which elements of the prefabrication processes in these countries are new.
- Document the job roles and skills applicable to the systems used.

Action: Conduct site visits to prefabrication facilities to document the systems involved in the production process which may be applicable to an Australian context.

2. Investigate and document different job roles involved for offsite prefabricated construction including those involved in onsite assembly.

- Identify and assess the skills applicable to offsite prefabricated construction
- Interpret the skills observed to develop a series of skill sets and possible career pathways.
- Document the skills required to complete job roles.

Action: Document job roles involved in the production process both on and offsite and how they may be applied in an Australian context.

3. Investigate and record the skill sets required to work effectively in the offsite prefabricated construction including those involved in onsite assembly and training currently provided.

- Identify through site visits, interviews and research, the skill sets applicable to offsite prefabricated construction
- Interpret the skill sets observed to develop a series of competencies.
- Document the skill sets required to complete job roles.

Action: Document skill sets involved in the production process both on and offsite.

5. IDENTIFYING THE SKILLS AND KNOWLEDGE ENHANCEMENTS REQUIRED

4. Determine the skills gaps that exist between job roles that currently exist in the established construction industry in Australia and those identified by 1, 2 and 3 above.

- Identify the skills gaps that exist between the identified job roles and current industry training packages.
- Interpret these gaps to identify a training and career pathway.

Action: Develop competencies in conjunction with industry partners to bridge the skills gaps and develop career pathway.

6. THE INTERNATIONAL EXPERIENCE

All visits and interviews described on the following pages were completed during 2015.

Kompetenz Zentrum Holzbau and Ausbau (Timber Competence Center and Extension)

March 4th to 6th.

This is a vocational training institution that specialises in the training of Carpenters. Approximately 1000 apprentices each year attend the college during their 3 year apprenticeship. They learn various skills using a range of traditional tools before choosing to specialise in different areas. These areas include restorations where they work on learning traditional methods for repairing historical buildings. Other areas of specialisation include roofing and prefabrication. The apprentices attend the training full time in their first year, then one day per week, with the occasional extra course during their second and third year. Kompetenz Zentrum also offers advanced training for supervisors and programs for existing and those wishing to become Master Carpenters.

Image: Apprentices learning about prefabricated construction

This not-for-profit organisation exists to maintain the proud history of Carpenters in Germany who see themselves as real craftsmen. Carpenters belong to guilds and part of their membership goes towards maintaining this training institution. As well as the training they provide legal, business and financial advice.

6. THE INTERNATIONAL EXPERIENCE

They also have a role to play in the recruitment of new apprentices.

Their training around prefabricated construction covers areas such as the joins and the process in general. They learn how to build the elements and all about the connections and correct placement of the vapour and water barriers. They have a special work where in the first week they build the elements on the floor and then in the second week they erect the elements, connect them together and complete the internal and external finishing. Once they are employed by individual companies they learn the companies own systems and methods.

The Fellow sat in on days three, four and five of a training program sponsored by the European Union for Irish members of the construction industry. This group included people such as builders, various trades, sustainability consultants and engineers. Under European direction Ireland is increasing the energy efficiency requirements of their houses. The training was delivered in the Centre of Excellence, which provides training for industry professionals. The program focuses on training around the passive house standard. It is hoped that by increasing the awareness and knowledge of the Irish construction industry to energy efficient building the practices will start to take hold. Approximately 750 individuals have attended the two-week live in program.

Day 1, March 4th – Presentation and Discussion.

The morning of day three involved a presentation about ventilation systems by Helmut Schindler from Maico ventilation systems. There are currently approximately 3,000 plus passive houses in Germany and Austria that require mechanical ventilation systems due to their building tightness. Ventilation systems allow the controlled exchange of indoor and outdoor air without losing any heat or cold to the outside. It promotes comfort and health as fresh air is added, consumed air and moisture is removed. This prevents issues of condensation which causes damage to the buildings structure and causes the growth of mould. Topics covered included the sizing and design of systems, the role of heat exchangers, layout and placement of supply and exhaust air ducts and air volume and duct sizing calculations.

The afternoon session was delivered by Achim Dangel a Master Carpenter. It commenced with a tour of the training facilities, an insight into training undertaken by apprentices and a tour of the timber museum. The session then went on to discuss various timber construction techniques and systems using a range of timber products. These included finger jointed structural timber, duo/trio beams, glue laminated timber, glulam ceiling, board ceilings, lignotrend, I-Beams, Kerto, cross laminated timber and a timber concrete composite.

He also spoke about a product from Lignotur which is a prefabricated flooring system that provides an effective sound barrier and is fully insulated.

Day 2, March 5th - Site visits.

The day started with a visit to a building site where a prefabricated house was being erected by a company called Weizenegger. Once the concrete slab was prepared and cured the house assembly began and lock up was achieved on the second day!

Image: Site visit to Weizenegger prefab house

The company was founded 100 years ago and now builds 20-25 houses per year and 5-6 schools. The wall, roof and ceiling elements are all prebuilt in the factory by a team consisting of only qualified Carpenters and some Master Carpenters. The factory is set up using a manufacturing system which includes the careful placement and storage of materials in a systematic manner that assists the workflow.

A Hundegger machine that is much like a computer controlled router cuts the slots where the separate timber pieces fit together. The frames are then nailed together on a giant table which has right angles on it to ensure the frame is square. Fermacell is then stapled on. Fermacell is installed on the internal wall instead of plaster board and gives the structure its rigidity. Insulation is then installed together with a vapour barrier and breathable membrane. The panel is then stood up and the windows are installed. The external facade is then added together with the first layer of render. In this case they use a compressed timber fibre product. Once the walls are installed on site, each wall is checked to ensure it is square and the correct dimensions. Each wall then has a sticker placed on it and signed off by the the installer. Rendering of the facade, sealing of the Fermacell, tiling and painting all occurs on site. Services are also all added on site, usually in a services cavity which is placed between the insulation and the Fermacell wall. This prevents damage to the barriers and insulation which would compromise the water barriers and thermal efficiency of the building.

6. THE INTERNATIONAL EXPERIENCE

Image: Hundegger machine

The importance of design was also discussed. The detail in the drawings is vital to ensure that everything fits together correctly so that moisture barriers are not compromised.

Fink Haus

This smaller family run company has 30 employees. This company builds about 30 houses per year. All are fully qualified Carpenters, except for five apprentices and two untrained helpers. The helpers role if confined to fitting insulation and general helping out. They build prefabricated houses as well as traditional carpentry work, restorations and roofs. Other contractors used in the process include painters who do the rendering and cabinet makers who work on the doors and flooring onsite.

The prefabricated elements are built on the floor which is perfectly level with metal 90 degree angles attached. There is enough space in the factory to work on 2 elements at a time. A small crane is used to lift and move the elements around. The elements leave the factory with the insulation, the vapour barrier and waterproof barrier, Fermacell and external facade already fitted. The first layer of render and internal paint is also applied. Windows are also installed and external blinds fitted. No wiring or plumbing is installed until the elements are onsite.

By working in this way, the company believes that it saves onsite time, reduces problems and saves time and money. This is also a much tighter control on the construction of the wall elements. Fink Haus has separate factory and erection teams. Blower door tests of their houses return results of 0.9 to 1.1 air changes per hour. This compares to Australia where 14 changes are common and better results range between 5 and 7.

Walser Holzbau

The Fellow was met and was guided by Rainer Walser whose role here is that of the designer. This company has specialised in building energy efficient houses for 15-20 years and has 25 employees. They produce approximately 12-15 houses per year all of which are passive houses. At the moment they are also building an apartment building that has 16 units, is 3 stories high and is built to the passive house standard. They have also produced a passive house indoor tennis centre, which despite being three courts instead of the previous one has reduced the energy bill from 60,000 euro to 1,500 euro.

The elements are assembled on low tables with square 90 degree angles. As with Fink Haus all the wall items are fitted inside the factory except for the services. Sometimes the wall elements are left open for the services to be fitted onsite and other times they fit a service cavity.

Walser emphasised the importance of having detailed drawings that show all the connections and how to eliminate the thermal bridging requirements by sealing correctly. They use a CAD program called SEMA.

Day 3, March 6 – Tour of Facilitites

This day involved a tour with Torsten Windmuller, the Director of International programs, of the facilities and a discussion of the programs offered.

Some definitions;

To meet the Passivhaus standard the building must fulfill the following requirements:

- The annual heating and cooling demand as calculated with the Passivhaus Planning Package must not be more than 15 kWh/m² per year in heating and 15 kWh/m² per year cooling energy OR to be designed with a peak heat load of 10W/m².
- Total primary energy consumption (for heating, hot water and electricity) must not be more than 120 kWh/m² per year
- The building must not leak more air than 0.6 times the house volume per hour (n50 ≤ 0.6 / hour) at 50 Pa (N/m²) as tested by a blower door.

Tuesday 10th March - Huf Haus

The Fellow then visited the Huf Haus prefabricated home manufacturer where I was guided around by Silke Thomas, the customer relations consultant. The company is 103 years old and has built 7-8000 houses in this period. They currently build 100 houses per year. They have 300 employees, divided evenly between those in the factory, those responsible for onsite assembly and administration. This includes those in offices across a number of countries. They have their own team of architects that produce the very detailed drawings for each design using CAD. They also have a number of subsidiary companies which they part own who are responsible for the installation of internal flooring, joinery, painting and electrical works. All wood waste and saw dust generated on site is used to generate heating for the whole site.

The visit comprised a tour of the factory and then a tour of the 5 display homes on the site. The houses are a distinctive style and feature a post and beam structure with lots of glass. Most of the houses also feature an atrium in the centre that brings even more natural light into the house. Because of this the glass panels need to be of extremely high performance. The glass panels are all triple glazed units and include a low ‘e coating’. The outside pane is 8mm thick, the middle pane 5 mm and the outside pane is 6 mm thick. There is a 12 mm gap between each pane, filled with Argon gas. The houses are built to an energy efficiency standard that is 55% of the German standard. The houses are heated and sometimes cooled with heat pump systems which can be boosted by geothermal or solar energy.

6. THE INTERNATIONAL EXPERIENCE

Image: A Huf Haus design

Construction takes place in two large warehouses, each approximately 50 metres wide and 75 metres long. The houses parts are constructed in parallel on the assembly line process. In this manner different parts of the house are constructed at the same time. The house beams and panels are all laminated timber. The process begins where the timber panels are all cut to the exact measurements of the design by a computer driven cutting machine. This machine also drills holes and shapes the end details where the pieces of timber are joined together. This emphasises the importance of the CAD design process as each piece of timber is clearly detailed in the design, as are all the connection points. The machine operator is a qualified Carpenter who has undergone internal training on how to operate the computer driven machine.

The panels are them assembled on tables with rollers to aid in their movement along the assembly line. Once the frame is constructed, a moisture barrier is added, then the insulation and then a breathable membrane. The roof beams are a thickness of 30 cm to cater for the thickness of the insulation. The staircases are also assembled on site. Fermacell is used on the internal surface with only the first coat of render applied to it. This is finished on site when the panels are connected and the joins can be filled in. Doors and the glass panels are also installed in the factory. By this time the heavy panels are lifted upright with a small crane and are connected to over head steel beams where they can be slid along. At this point the render and paint is applied to the external facade which is made of high density polystyrene. This again adds to the insulation. Special connections are also added at this time so that the panels clip together onsite.

Plumbing is added to bathroom and kitchen area panels. This is done by a Carpenter who is also trained in house. Electrical cables for the lights and external blinds are also added at this time. Even garage the garage door is prefixed. In some cases hollow tubes are put in place so that cables can be

pulled through at a later date or hollow beams are used in the structure when cables need to be run through them. A separate team is responsible for the onsite assembly of the panels.

The second part of the visit involved a tour of the 5 display homes on site. The flagship was the Huf Haus Art 9. This house covered an area of 300 m2 on each of its 3 levels. An internal atrium ensures a supply of natural light all the way through the house. It has a solar panel system which is integrated into the roof structure. There is also a solar hot water system which boosts the water used for the hydronic heating system. The system can also be used for cooling where required. This is a very upmarket product.

A more modest version is the Huf Haus Modum 7:10. It is 170m2 in size and uses a different building system to their traditional house. There are less exposed post and beams, less glazing and more solid panels. It is a more typical house with more modest fittings and ensuite. The price is 400,000 euro for the structure above the basement if built in Germany.

Image: The Huf Haus Modum

The build time is 9-10 months from the time the contract is signed until the handover. It takes 6-7 months from the time the building permit is received. The houses come with a 4 year warranty.

Other than the basic on the job training, there seems to be no other training program for the employees. All the workers in the factory are trained Carpenters. There is a trainee program for the architects which introduces them to the Huf Haus way of doing things.

6. THE INTERNATIONAL EXPERIENCE

Thursday 12th March – WEINMANN Holzbausystemtechnik GmbH (WEINMANN)

WEINMANN is a manufacturer of computer numeric controlled (CNC) machines that are used in a production line to automate the building of frame elements. The company was founded 30 years ago and in 1992 they installed the first production line for a local company that now builds 700 houses per year. This company has now produced 20,000 houses so far. The machines are able to transpose CAD drawings to the built form. The company is now part of the HOMAG group which is a manufacturer of wood processing machines, cabinets, floors and windows and has 5600 employees worldwide. There are 130 people employed at the Weinmann plant at St Johann, consisting of process workers, mechanical engineers and software engineers. They also have production facilities in Poland, Sao Paolo and North America which produce mostly the steel tables on which the elements are built. The more complicated CNC machines are produced in St Johann.

The machines they build take in the whole production process. A beam machine cuts the studs to the correct size according to the information feed to it via the CAD drawings. It also cuts in notches in the top and bottom plates to indicate where the studs fit in to further reduce the chance of operator error. The frames are put together on a framing bench which ensures they are square. Once the studs are nailed into place automatically with a nail gun, the internal wall can be stapled on, automatically after the moisture barrier is added. The insulation can then be installed, the vapour barrier and the external facade can be stapled in place for a fully enclosed element. Services are added via an internal service wall. This prevents damage to the moisture barrier and insulation removal.

Image: Weinmann machine cutting excess internal lining.

In terms of machine operators the person actually working the machine does not necessarily need to be trade qualified as the machine takes the detail directly from the CAD drawings and very little

knowledge of the construction details needs to be known by the operator. In some cases, having a qualified Carpenter as the operator can actually be a hindrance if they override the CAD design process. In this case a manufacturing process worker is better value as they are trained the follow the process. This is also of benefit in a time when apprentice numbers are falling leading to a shortage of qualified trades. Quality control due to a lack of qualified trades is overcome by using an engineered factory produced process. Intergenerational change also means that people are more used to working with computers and this makes it easier to train people to work on these machines.

The manufacturing system used also strives to reduce waste produced by using wood fibre or cellulose insulation made of waste paper. There is also a move to have spray foam insulation used, which can also be automatically applied by the machine. The advantage of the timber construction process over the use of structurally integrated panel systems (SIPs) is that it is simple to make mistakes using the SIPs panels which means water infiltration problems. The core of SIPs panels is usually Extruded polystyrene which creates waste that is difficult to dispose of.

Other types of waste are reduced by using manufacturing principles that require detailed drawings before production actually starts. All pathways and conduits for the electrics and plumbing are preplanned. Like a BIM system this means that potential problems can be picked up during the design process and rectified. It is less expensive and time consuming to fix these problems at the beginning rather than at the construction site. The quality control associated with the manufacturing process and a BIM clash detection system also increases the chances of mistakes being detected. There is no reliance of people on the construction site to pick up the mistake.

WEINMANN provides advice to companies who are looking at setting up production lines. They work out what they want to do and then design the machinery and lay out to best suit. For example if the client only wants to do framing then they will require different equipment compared to building fully constructed elements that have the insulation and internal and external walls added.

They also run training programs for their clients. They have their own Carpenters that run the training courses for the clients and train their clients people on how to use the machinery and the computer interfaces. Importantly the training also covers how the elements are designed to connect together on site. A vital part of the construction process where errors can eliminate the advantage gained from the prefabrication process. The training also covers aspects of working in a manufacturing environment, such as not watching the machine at work but do other preparatory work in the meantime. Where to put the materials for improved workflow also improves efficiency.

Site visit to Tussa Haus

In the afternoon we visited Tussa Haus, who do not actually build houses but build the elements for other builders to order. The company delivers for 7 different builders and its processes are capable of building the walls differently according to different specifications. With workforce of 30-40 employees they are able to produce enough elements for 80 houses per year.

This company uses a Weinmann beam manufacturing machine that optimises the use of the timber lengths received by working out what lengths can be cut to minimise waste. The machine at this facility was operated by a qualified Carpenter who was trained on how to use the computer interface by a Weinmann Carpenter.

The frame is then put together on a table by another machine that shows where the timber pieces are to be placed and then nails them together. The pre-cut internal Fermacell panels are then automatically stapled on by the machine, together with moisture and vapour barriers, insulation and the external facade. A basic framing and nailing machine used for this process costs about 200,000 euro. The

Fermacell is no longer glued in place as the staples are adequate. This reduces the use of a non environmentally friendly material. For the same reason expanding tape is used around window to seal for air tightness rather than expanding foam. The cladding system and external render comes with a warranty. The Wienmann machinery is installed on rails on a raised timber floor. This not only allows for services to be installed below but the timber floor is also more comfortable for people to work on all day.

Hollow conduits are also pre-installed to allow electrical wiring to be pulled through by the electrician on site, who then signs off on the installation. Plumbing in some areas is also pre-installed, for example in the bathroom. In this case the panels are screwed on temporarily so they can be removed for onsite checking by the plumber.

Typically a 150-180 square metre house can be assembled to lock up stage in one day.

Friday 13th March – WEINMANN, Site visit to Schworer Haus

The Fellow met with Jocham Renner, the company Manager. The company was established about 60 years ago and now builds approximately 800 houses per year and a number of two, three, and four storey apartments. This mostly takes place in an area measuring approximately 400 x 50 metres. They began automating the construction process about 30 years ago. They now have approximately 1,000 employees, which includes their own delivery and installation crews. They also control the process and quality right from the beginning by buying the trees directly from the forest and processing the timber in their own sawmills.

The timber studs come pre-cut from the sawmill to the framing machine where they are fixed in place by an automatic nail gun from a CNC machine working from CAD drawings. At the same time internal sheeting is cut to size for the same elements. The sheeting is then put in place using a machine to pick up the sheets and place them onto the frame. They are then stapled automatically in place. Their wall design has a services cavity that is separate to the cavity that contains the insulation and moisture barrier. This prevents the insulation layer being compromised and it's effectiveness reduced. It also stops damage to the moisture barrier which would allow water vapour to enter the wall cavity and cause water damage.

All the electrical and plumbing rough ins are completed in the factory according to the design and approved engineering requirements. The benefit here is that there is less time and material wasted. The exact installation time can be calculated leading to more accurate cost estimation.

The plastering and external rendering is also completed in the factory. This provides more supervision over the skills of the people, the quality of the work and ultimately less expensive rectification problems.

Image: Completed panel ready to ship

They also work with a flexible workforce that allows the company to cope with the ups and downs in production. During the quieter times of the year the employees are paid even though they do not attend work, but will make up the hours during periods of increased demand for the houses.

Their website has a video that shows the installation of one of their houses on site in one day, to lock up stage.

Monday 16th March - City of Munich

The opportunity was taken to attend an information presentation and discussion session with Herbert Giptner (Building Services - City of Munich) and Reinhardt Kleinoder (Department of Health and Environment - City of Munich). The presentation covered the City's policy on the requirement for buildings built and maintained by the City to be healthy and sustainable, with minimal impact on the environment. Reinhardt is responsible for the implementation and co-ordination of these policies across the different departments.

Directions into the requirements are taken from the states building regulations. Using a combination of life cycle assessment and other information on health impacts they produce a list of materials that are to be avoided and the reasons for this. This is a compulsory part of major projects, but in most projects only certain assessments are carried out such as building heating demand. Because of the age of some of the buildings and the methods of construction in the past, it is not always possible to eliminate some problems such as mould, however the problem can be reduced by the use of different materials.

With existing buildings such as schools and kindergartens the council regularly carriers out monitoring of the indoor air quality to identify any potential problems. Where initial concerns are identified the

Department of Health will contract an external provider to confirm the problem and suggest any possible remedies. These may include works to improve ventilation, renovation of the building or the replacement of materials contributing to poor indoor air quality. Some of the materials that are considered hazardous enough for removal include asbestos, polychlorinated biphenyls in the expansion joints between concrete slabs and formaldehyde based adhesives.

While the Green Building Councils LEED certification system is used for certain projects the State also has the DNGB certification system which considers ecological, economic, social and cultural factors. Projects are awarded a gold, silver or bronze standard. A new building for the Department of Environment and Health due for completion in 2020 will be be rated with the DGNB and will be built to the passivehaus standard. The objectives are to be achieved by ensuring the requirements are met at the design stage and by the inclusion of specifications in the tender documents. The project will is also monitored during construction for quality assurance and all the building materials used are to documented.

The council also has requirements that it places on the construction of new buildings within the municipality. They require the buildings to consume less energy than permitted by law, reduced heat loss through thermal bridging, insulating against summer heat rather than simply providing mechanical cooling, no PVC (except with few exceptions), no tropical timber and the use of district heating where available, heating with solid or liquid fuels only. The construction of buildings that consume less energy than the required standard is encouraged through the provision of loans with lower interest rates when buildings meet various reduced levels.

For buildings built for the City of Munich these requirements also include the requirement to reduce energy consumption for heating by 30% less than the standard and no large scale use of aluminium due to the environmental damage from extraction and energy consumption during production. They also promote the use of wood as a building material and where possible exclude the use of CMR (carcinogenic, mutagenic, toxic to reproduction) materials. The flooring is required to be linoleum, there is to be no use of chlorinated hydrocarbons, mineral fibre insulation is the preferred option and recycled products are to be used where possible.

The City also owns a number of housing companies that build social housing. These houses are also required to exceed the minimum regulated energy efficiency standards. They also have their own technical and environmental policies, but these are not as detailed as the standards of the Department of Building.

Tuesday 17th March - City of Munich

The council also functions as an advisory service for citizens and professionals. To do this it maintains the Building Centre Munich, which I attended as part of my visit. People can attend here for advice and to view the latest in energy efficient and environmentally friendly products that are on display. There are also regular presentations open to the public to attend and they also attend meetings of consumer organisations and provide information to trade journals.

Staff of the centre also provides advice to industry professionals, attend trade shows and provide input to WECOBIS, the internet platform of the Bavarian Architectural Association and the Federal Ministry of the Environment. They also provide guidelines and information to the federal government's portal on Sustainable Building.

Thursday 19th March – Hans Hundegger AG

Hundegger is a manufacturer of timber processing machinery that includes automatic cutting machines, planers, gantry-type machining centres, automatic panel processing machines, profile wood elements production lines and handling systems. The universal, flexible machines are used in all timber construction sections from carpentry joining, contract joining, log house construction, prefabricated house construction, gluelam joining to the production of playground equipment.

This family owned company has been in existence for approximately 37 years and has a presence in 45 countries. The company currently has about 350 employees, including 28 Apprentices, 99% of which are employed by the company once they have completed their apprenticeship. Their training is supervised by a head engineer to ensure they actually learn so they are of value to the company in the future. They are seen as valuable because their training ensures they are already familiar with the companies systems.

They feel that it is important to use a qualified Carpenter who has been properly trained to use the Hundegger machine and can read the drawings and plans effectively. So rather than simply doing what the machine tells them, they are able to think about what they are doing and are more likely to pick up any mistakes. This ensures that mistakes don't make it to the site where rectification can be expensive. They have also found that the onsite construction crews are generally younger and move to the factory environment as they get older. This has the effect of bringing valuable onsite knowledge back to the manufacturing environment. A flexible workforce is also seen as an asset as the workers are able to move around and work on different machines as required and also reduces boredom.

Site visit to Baufritz

Baufritz has been in operation since 1896 when it started as a carpentry practice. In the 1970s they started to build houses and in the 1980s they became an environmental and health conscious builder by taking on a goal of not using any products that harmed their clients, their workers or the environment. The timber frames they use is from sustainably sourced plantations and is not treated in any way. They also do not use any fiberglass in their operations. They produce approximately 188 timber framed houses and a number of commercial structures each year. Their houses are sold across Europe and they have approximately 300 employees.110 of these are in the plant, 60 work on onsite assembly, plus sub-contractors as required and the rest are in the office or sales areas. The employees in the plant are just about all qualified Carpenters of joiners many of which started as apprentices with them which means they become very familiar with the company's systems.

A Hundegger machine is used to prepare the timber beams by using information directly from the CAD drawings. Training for new users of the Hundegger machine is carried out by their operators. The machine not only cuts, drills and machines the timber, it also prints the name of the project and the element number onto the timber.

The frame is then constructed on tables where a vapour barrier is added and the plasterboard stapled on. The frame is then flipped and wood shavings are added for the insulation. Some of these wood shavings are produced from offcuts in the plant and the rest is brought in. There is no chemical treatment of the insulation. It is instead treated with whey which acts as a natural fire retarder and soda whose high alkalinity inhibits mould growth. Using the wood shavings for insulation means that is easier to ensure that there are no gaps, which can occur when using insulation that needs to be cut to fit.

The panels are raised vertically and the facades and the first coat of render are added. Guttering brackets, flashing, windows, roofing material, shutters and even solar panels are then fitted in the factory. Ducts are fitted in the factory to allow for the passage of electrical wiring to fittings such as the shutter motors. Water, sewerage pipes and toilet tanks are also preinstalled by plumbers in the factory.

6. THE INTERNATIONAL EXPERIENCE

A services cavity is added to the internal wall to prevent damage to the insulation layer and vapour barrier by contractors onsite or by the owners when they hang pictures.

The panels are shrink wrapped and then loaded onto trucks for transport in the correct order to be ready for unloading onsite by a small crane. The maximum length they build to is 12.5 metres. The shrink wrap is recycled. About half the people who erect the houses are their own employees and the rest are subcontractors, as are the fit out crews. The sub-contractors which include the assemblers, fork lift drivers, mobile crane operators are also trained to understand their systems.

Assembly onsite takes about one day for a small house. The roof tiles are added on the second day and then the interior fixtures of the house are fitted. This involves the installation of tiles, appliances, taps, flooring and the painting of the walls. Completion takes about three months. The final coat of render is added onsite by sub-contractors.

Bauftiz has a display area where people can sit with an interior architect, view and choose their colour schemes, tiles and fittings. Typical houses cost about €300,000 for a 170m2 house with high quality fittings. This excludes the basement.

Image: A Baufritz design

Friday 20th March – Hundegger, Site visit to Prutscher Holzbau

This company started as a carpentry practice before moving to house construction. They produce about 15 houses per year and have about 15 employees. This is consistent with other prefabricated house builders who seem to have a ratio of one employee per house built per year.

The small size of this company and less space means that they have to be more flexible. The process is less automated and the elements are constructed on the factory floor with the paper plans nearby to check the Hundegger machines output.

Their small size and flexibility means they are able to offer elements constructed from different components. They can offer panels with or without glue, wood composite of panel systems and with different types of insulation.

Again the workforce is made up of qualified Carpenters and is generally stable. Attention to detail is critical, especially in the taping of the membrane joints, which is emphasized during their training.

Site visit to Mayr and Sonntac

Mayr and Sonntac is an example of a small flexible company, mainly servicing the local market in a 15-20 kilometre range. They are mainly manufacturers of massive timber beams for barns but also produce nailed wall panels which they supply directly to builders.

The wall panels are cut to the required size and planned to remove small variations in thickness. All the sawdust produced is made into pellets onsite which are then sold, resulting in very little waste from their production process.

Image: Panel about to be moved for painting and rendering

6. THE INTERNATIONAL EXPERIENCE

Tuesday 24th March – Rosenheim University of Applied Sciences, Germany

Professor Rainer Grohman, from the Faculty of Wood Technology and Construction introduced the Fellow to the university and their programs. This university runs a number of academic programmes in wood, energy and construction that are highly regarded by the industry. Their programs include a number of Bachelor's and Master's Degrees including;

- Energy and Building Technology (Bachelor´s Degree)
- Windows and Facades (Executive Master´s Degree)
- Wood Building and Construction (Bachelor´s Degree)
- Wood Construction for Architects (Executive Master´s Degree)
- Wood Technology (Bachelor´s Degree)
- Wood Technology (Master´s Degree)
- Interior Engineering (Bachelor´s Degree)

These courses offer new perspectives on all aspects of wood construction from innovative wood and lightweight construction resulting in the energy-efficient optimisation of building shells, through to use of renewable energies, facades, energy technology and climate-friendly energy generation.

They teach three courses at the undergraduate level. Wood technology has been taught for about 90 years and covers industrial processes. It has a largely engineering focus with some management subjects. Graduates usually end up as engineers and production managers. Course content includes production management, how materials work together and the machines in the construction process. There are a number of CNC machines available that the students learn to work on and program as part of their course. Students also learn about the importance of optimising the production process from the beginning to reduce problems downstream for efficient logistics. Important knowledge when working with prefabricated construction system where they need to know how to plan the construction process and how to set up and design the plant for prefabricated construction.

Wood building and Construction is a design focused course where students learn to use CAD and write software programs for CNC machines. The interior engineering course has content that covers the interior parts and assembly of a building and produces a graduate with knowledge somewhere between and interior architect and builder.

The undergraduate courses run for three to four years, and 80-90% of their students have already completed an apprenticeship. This industry experience is further enhanced by a placement as an intern before completing their degrees. The Masters program covers mainly industrial processes, management and leadership. They have about 10-20 students in their Masters program and about 600 in total in the faculty. The faculty also has a number of research labs which investigate the effects of climate on wall elements, measure thermal conductivity, loads on building elements, simulate earthquakes and measure the tensile strengths of timber. They also conduct research on fixing systems for wall panels, including different screws and dowels.

7. KNOWLEDGE TRANSFER: APPLYING THE OUTCOMES

A range of construction techniques and systems were observed during the fellowship related to the size of the companies and the volume of panels constructed. Different levels of mechanisation were used by companies of different sizes. This also means that different investments in the equipment can be made to reflect the different outputs by these companies. The basic technique used by smaller companies involved the cutting of the timber for bottom and top plates by machine from physical plans using a CNC machine. These were then put together on a table to square up frames and the building elements manually constructed by qualified Carpenters. Plaster, insulation, water proof and permeable membranes, windows, shutters and even the render was applied in the factory. Services such as plumbing and electrical were added on site.

Larger companies used more mechanisation in the construction process. An operator used a CNC machine to prepare the timber pieces from CAD drawings. These were then placed in the appropriate place by a qualified Carpenter and the frame was then nailed together automatically. Internal walls are then added and then automatically cut and stapled in place. The plaster, insulation, membranes, façade and sometimes some plumbing was completed in house.

In Germany most of the roles on the factory floor were carried out by qualified Carpenters. These people were often given basic training by the company in their own systems or on how to operate the CNC machines. These findings were similar to those of a previous Fellow, Daly (2009). He identified that it wasn't so much the occupational skill sets that were required, rather the soft skill sets such as communication and collaboration.

In Australia a range of new roles and skills required by this emerging industry were previously identified in a project by this Fellow (Alviano 2014).

The job roles identified and the additional skills required by the prefabrication industry included:

Designers

Required to have knowledge of lean manufacturing to be able to design out waste and to develop designs that considered the manufacturing and assembly process. They also needed to consider manufacturing tolerances and quality assurance processes in their designs to allow for the fact that their designs would be built and moved around before installation.

Trades

(Carpenters, Electricians, Tilers, Plumbers, Painters, Metalworkers): The ability to read drawings and ensure they are building to exact specifications will be an important part of their job. They also need to be aware that in a manufacturing environment, speed and timing is vital, as is attention to detail and quality outcomes.

On-site assemblers

(Trades, riggers, crane operators): Once the project reaches the on-site assembly phase then speed, quality finishes and knowledge of construction systems and processes are vital. They must be able to work in a team environment to ensure a smooth operation. The project needs to be managed effectively in a time constrained environment. They will also need to be aware of workplace health and safety issues on a construction site. Knowledge of logistics will also keep the process flowing smoothly.

Team leaders

The focus is again on a smooth and efficient operation that is time conscious. As such being able to manage a team to deliver quality products in a safe environment is vital. They will also need to be able

to read complex documentation to ensure that processes are being adhered to.

Logistics

A move towards more of a manufacturing environment requires the effective use of time to deliver projects cost effectively. Effective logistics means that resources are used effectively and waste through lost time is reduced. This is especially critical for the just in time delivery of supplies and the reduction of crane hours during on site assembly.

General labourers / assistant

Need to be aware that what they produce needs to meet the specified tolerances and be of good quality.

Project Managers

Need to ensure the effective use of time to deliver projects cost effectively. Often responsible for getting trades to work as a team and effectively manage budgets and project timing.

Manufacturing engineers/technicians

In order to develop systems, processes and materials for a manufacturing environment they needed to have knowledge of designing for manufacturing and assembly, construction systems and quality assurance.

OH&S Officers

Will need to be flexible enough to move between manufacturing and construction environments. They will also need to make sure that people under their responsibility are also able to do this.

Construction manager

They will also need to be flexible enough to move between manufacturing and construction environments. This will require a knowledge of both manufacturing and construction processes and systems.

It is clear that many of the roles just described require knowledge of both manufacturing and construction processes, skills and knowledge. This will require existing workers in manufacturing to increase their knowledge of construction processes, skills and knowledge and those in construction to do the opposite. Just how much extra knowledge they will need will depend in their job role. New people looking to enter the prefabricated construction industry may look towards blended qualifications that encompass units of competency from both the manufacturing and construction packages. A number of possible training programs were identified from the manufacturing and construction packages that could provide the skills necessary to cover the gaps identified. These included the;

- Certificate II in Process Manufacturing
- Certificate III in Process Manufacturing
- Certificate IV in Process Manufacturing
- Diploma of Production Management
- Diploma of Building and Construction (Management)

Other qualifications from the training packages identified do not allow enough electives to be chosen from alternative packages to cover the necessary skills gaps. Closer scrutiny of the packaging rules and Units of Competency within the qualifications will show if the qualifications identified above are adequate or if new hybrid qualifications in the field of prefabricated construction systems need to be developed.

The areas of knowledge transfer include the following:

1. *Increase the knowledge of the benefits of prefabricated construction to both the industry and the community in Australia.*

   This has already commenced with the fellow delivering a number of presentations at a conference and to members of the construction industry. Articles have also been provided for a number of industry magazines. Discussions have also been held and will continue to be held with the Department of Education and Training and the Department of Economic Development, Jobs, Transport and Resources.

2. *Use the skills sets and qualifications identified from the Australian Qualifications framework to determine their appropriateness for providing people with the necessary skills to work in the prefabricated construction industry.*

   These skills range from those required by designers who need to apply a greater level of detail and planning typical of a manufacturing mindset, to the attention required of someone on the shop floor to the installation of materials and products to ensure the building operates effectively. Further research will determine if the qualifications identified will be appropriate by conducting a deeper search of relevant units of competency from the Australian Qualifications framework. This will occur as the industry matures in this country and demand for the upskilling of the workforce increases.

3. *Develop training content for the units of competency with particular relevance to the prefabricated construction industry.*

   The research showed that the manufacturing environment in Germany resulted in quality buildings where the attention to detail meant that the buildings had much lower air infiltration rates and therefore energy use than Australian buildings. Any training developed will have to reflect the greater attention to detail required in a manufacturing environment. This will occur as the industry matures in this country and demand for the upskilling of the workforce increases. This can occur in collaboration with industry, government and training providers.

8. RECOMMENDATIONS

Prefabricated buildings are produced in a manufacturing environment that requires an attention to detail from the design stage, through the fabrication stage, to the final installation. For the industry to mature in Australia existing workers in manufacturing will need to increase their knowledge of construction processes, skills and knowledge and those in construction to understand the concepts around lean manufacturing.

The following recommendations are being implemented by the Fellow in assisting with the increased take up of Prefabricated Construction in Australia.

Government

- Continue to work with state government to identify barriers to the adoption of prefabricated construction in Australia by;
  - » Participating in industry round tables
  - » Providing advice as required.
  - » Indentifying changes to building and inspection regulations
- Provide support the development of training programs
- Provide support for people transitioning from the manufacturing industry for re-skilling.

Education and Training

- Determine if the qualifications identified in Section 7 are able to provide the skills required for the prefabricated construction sector, and where deficiencies are found identify the need for new qualifications.
- Develop content and material for the qualifications identified in Section 7 to for the delivery of training programs.
- Continue to work with RMIT University on the project titled, “Efficient construction: Analysis of integrated supply chains for innovative off site manufacturing”.
- Establish contact with and work with the ARC Training Centre for Advanced Manufacturing of Prefabricated Housing administered by the University of Melbourne.
- Develop professional development programs for staff of TAFE Colleges and private registered training organisations.

Industry & Professional Associations

A number of presentations have already been made to;

- Frame Australia, Conference and Exhibition 2015, “Labour skills and training for prefabricated construction”, June 1st, Park Hyatt, Melbourne
- The Annual dinner of the Wodonga Section of the Master Builders Association of Victoria, May 19th
- The Board of the Master Builders Association of Victoria, June 23rd
- The Country Sector Committee of the Master Builders Association of Victoria, June 23rd
- The Housing Sector Committee of the Master Builders Association of Victoria, June 24th
- The Materials, Manufacturing and Suppliers Sector Committee of the Master Builders Association of Victoria, June 25th

8. RECOMMENDATIONS

- The staff of the Master Builders Association of Victoria, June 26th
- The Bendigo Section of the Master Builders Association of Victoria, July 22nd.

Dr Alviano will continue to increase industry awareness of prefabricated construction through presentations, articles in industry magazines and conference presentations:

- The Gippsland Section of the Master Builders Association of Victoria Annual Dinner, October 22nd.
- Article “Prefabricated Housing – Lessons learnt from overseas”. Master Builder magazine, July 2015
- Article “Prefabricated Housing – Lessons learnt from overseas”. Australian Forests and Timber News, July 2015
- Deliver presentations as requested by other industry associations and training institutions.

Community

Dr Alviano will also develop public understanding of the increased build quality of prefabricated housing and the advantages through presentations and articles as requested.

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