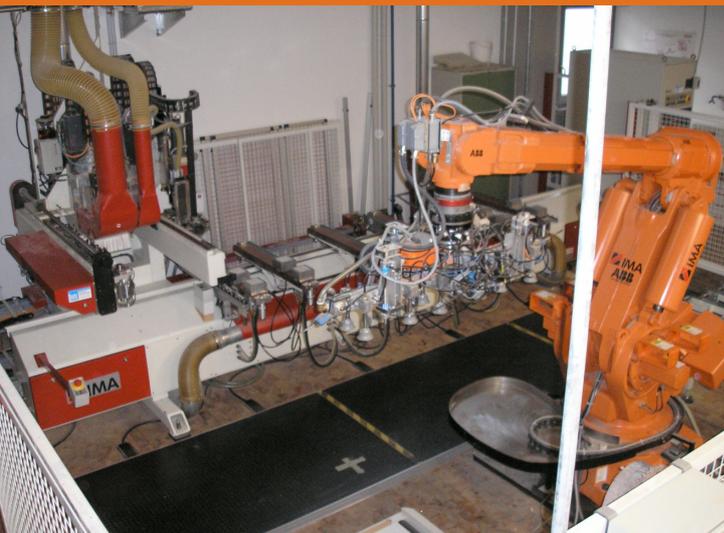


Innovative and Interdisciplinary use of

Computer Numerical Control (CNC)

Manufacturing Solutions for the Design and Manufacture of Furniture
and Building Products using Limited Resources in a Targeted and
Effective Manner



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ISS Institute/TAFE Fellowship

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TABLE OF CONTENTS

Table of figures	5
Acknowledgements	6
Visit contacts	8
Executive Summary	9
Acknowledgements	12
Awarding body/s – individuals	12
Fellowship sponsors	12
Other support and assistance from:	12
International Specialised Skills Institute	13
Skill Deficiency	13
Overseas Skills Acquisition Plan - Fellowship Program	13
ISS Research Institute	13
The Australian Context, an overview of CNC processing in the Australian furniture industry.....	15
Quality systems	17
CNC training	17
Manufacturing design.....	19
Organisations that have an impact on the industry (Victoria).....	21
Aims of the Fellowship	22
Implementation	22
Skills gaps	25
Furniture design.	25
C.N.C. training regimes.	25
Part fixturing on C.N.C. machinery.	25
C.N.C. tooling.	25
Design and manufacturing.	26
Quality systems.	26
Waste minimisation.....	26
Emerging technology.	26
Small batch manufacturing.	26
Problem solving.	27
Manufacturing design.....	27
What is CNC manufacturing?	28
History of CNC wood working machinery	28
Advantages of CNC processing	30
CAD-CAM.....	31
CAD (computer aided design)	31
CAM (computer aided machining or manufacturing).....	32
European perspective.	35
Materials.....	35
Machinery	36
Quality.....	37
Software	37
Training	38
Design	39
Automation.....	39

Tooling	39
High speed cutting.....	42
Fellowship program	44
Itinerary	44
Visits	45
Ligna Plus machinery fair, Hannover, Germany.	45
Fachschule Holztechnik, Hildesheim Germany.....	48
Weeke Bohrsysteme GmbH, Gütersloh, Germany.	49
Danish Technological Institute, Odense, Denmark.....	50
International Activities.....	50
Mission.....	51
Odense University College of Engineering, Odense, Denmark.....	53
Carl Hansen and Son, Aarup, Denmark.....	55
Hans J Wegner	55
The factory	56
Sauer-Danfoss	59
Skiolo Mullerup	60
Berne University of Applied Sciences (HSB).....	61
Wood Welding project, Berne University of Applied Sciences	63
Stuber	64
Fraubrunnen	65
Fluck Werke,	67
Schule fur Holzbildhauerei	69
Fachhochschule Rosenheim, Rosenheim, Germany (University of Applied Sciences).	70
Unifor, Turate (Como), Italy.....	73
Outcomes of the fellowship	75
Recommendations	76
Government.....	76
Industry	76
Professional Associations.....	77
Suppliers.....	77
Training providers.....	77
International Specialised Skills	77
References	79

Table of figures

Figure 1 Study communication pathways	23
Figure 2 Modern CNC Router.....	29
Figure 3 CNC processing centre	30
Figure 4 Advantages of micrograin carbide for CNC machining	40
Figure 5 Thermogrip CNC tool holder.....	41
Figure 6 HSC Graph.....	43
Figure 7 Four and a half axis technology from Homag	45
Figure 8 Thermoplastic dowels used to assemble furniture.....	46
Figure 9 Loreley design using CNC technology	46
Figure 10 Fachschule Hildesheim and student design	48
Figure 11 Ruler assembly line and robot track	54
Figure 12 Elbow chair by Hans Wegner	56
Figure 13 Specially made clamps hold the chair until dry	57
Figure 14 Cow cleaning equipment at Skiolo Mullerup.	60
Figure 15 The Swiss education system	61
Figure 16 Continuous sanding machine and robotic window assembly	62
Figure 17 Stuber head office and beam manufacture.....	64
Figure 18 Fraubrunnen furniture and automated CNC technology	65
Figure 19 Fluck Werke Kinder furniture.	67
Figure 20 Fluck Werke and Robotic installation	68
Figure 21 Swiss carving school, Brienz.....	69
Figure 22 CNC machining centre and Robot at Rosenheim Fachhochschule	70
Figure 23 Unifor product and form-work.	73

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Executive Summary

There does not appear to be a uniform method of delivering CNC training through the countries we visited in Europe. One impression was that there is a lot of learning through trial and error. As we understand it there is some CNC training delivered at years 11 & 12 in the German post primary system. The years 11 & 12 in Germany are specialisation years in specialised schools. There are three streams with one somewhat like a technical school. The Danish and Swiss experience seems similar to what happens in Australia. That is, the supplier can program machines and/or the machine supplier provides a short introduction course. Machine suppliers provide short course training but this of limited scope. It could be assumed that broad based training on CNC is not provided. The answer is a little confusing. There is general training at a higher theoretical level. This includes G-coding and a better understanding of drawing to component. It would appear that CNC training in Australia exposes students to this technology at a lower level than in Europe.

The Danish education system provides some interesting options for us. These include a closer teacher to student contact. This was also evident in Germany and Switzerland. Individual learning plans for each student will assist in meeting the diverse needs of our Industry. Team teaching could be used to put more teachers with various backgrounds in front of the students. Denmark uses their facilities in a flexible manner, offering all of their facilities to whoever require its use. Two further observations are that Industry is very involved in the trade education system, and dropouts are followed up with a view to retaining the knowledge in the trade area.

New design and automation of CNC rails and pods allow for more flexible positioning of the pods and quick set up times. Variety in pod shape and hold down type (vacuum, clamp) can allow for greater concentration of force. Pneumatic clamps can be used in conjunction with custom-made hold down devices. These pneumatic clamps are operated remotely from the CNC machine. That is that they are not part of the CNC compressed air system or the drilling and routing program. They can be part of a robotic component loading program and in these cases are partnered with CNC drilling and routing programs. Laser lights can be used to preview component placement. This can assist in fine-tuning pod placement and/or component layout on multiple component hold down devices. A greater understanding of mechanical fixing, jig construction and part holding would benefit Australian companies.

Much can be discussed about tool magazine and collars. ISO and HSK were the main two types we observed with HSK appearing to be the popular choice. HSK is the choice where heavier solid timber work is required as, due to its design, it has surfaces that lock more firmly into the electro spindle (Router), however at the same time its design makes it more susceptible to fine dust entrapment. To the later aspect dust clearing air jets (mounted on the tool

carousel) and good housekeeping techniques should overcome this issue. The ISO should be considered where the predominant work is with MDF and other fine dust materials as its design is less susceptible to fine dust build up. It was also our impression that the ISO was less suitable for very high-speed applications. Tool design is ongoing like all technologies and companies like Leitz are at the forefront. Cutting tools can be coated to reduce friction and therefore reducing heat in the cutter, allow for quicker feed speeds and reduce the power consumption of the motor. Spiral cutters may be used for cleaner cuts with fluting design for waste removal and noise reduction. Balancing of cutters and collars along with improved cutter holding capabilities open the opportunity for higher rpm and feed speeds. The use of Shrink fit and Tribos® systems (see section on tooling) are starting to see their way into the industry. Tooling is able to deliver improved quality and performance and is an area that should be more fully investigated and taught in our education system.

The contemporary European trends lead itself to CNC manufacture. CNC is becoming more capable at complex component production and with the increase in the use of robots, materials handling, assembly, sanding and material finish treatments are becoming more automated. High end automation is not always quicker but it is consistent and can run 24 hours a day with far less labor costs and in these terms are very competitive and in some cases beyond competition with lower technology countries. Classic and contemporary designs to varying proportions are all possible to be produced with CNC and Robot Technology. What were very evident were the companies that specialised in one form of manufacture or another. Invariably, work that would be done in the Australian factory would in Europe be outsourced. This work included low-skill jobs that were cheaper from another supplier, such as dressing of raw lumber. Other outsourced jobs included components with specialised machining requiring expensive tooling. The Australian way of doing it all in-house could be inefficient and greater sharing of work between companies would assist in productivity and lower end costs.

The materials available often influence design and of course, what the market will accept. This is similar to Australia. In the case of Carl Hansen (Denmark), the designer has what amounts to absolute power. The designs of Hans Wegner are made under license and the designer's daughter who has authority of the original design, is able to stop production if an error is found. In the case of Carl Hansen, production levels are limited to ensure the quality is maintained. European manufacture is either large quantities or small batches. The ranges of furniture appeared to be limited and not too many options were catered for. Some very interesting and innovative designs were seen using plywood as a raw material. The products were shelving units, cabinetry and chairs manufactured on CNC equipment and "snapped" together using the material's inherent bending qualities to fix the parts together. More use of innovative designers would have a positive effect on Australian product. A focus on design AND CNC manufacturing should be investigated. The funding of a centre of excellence for design and CNC manufacture will be a positive step towards a design culture that is able to work in a modern manufacturing environment.

We visited several companies looking at lean manufacturing. The companies had on-site, students from the Danish Technological Institute doing projects on lean manufacturing. It is common practice in many Danish companies to introduce lean manufacturing technologies incorporating CNC installations into the work place. Lean manufacturing is also used without CNC and provides an edge to Danish companies working in a small market, similar to Australia. New process planning software can identify bottlenecks within the company. Machinery companies are pushing to sell complete systems; in other words fit out an entire factory with all the machines required to produce that factory's components for their product range together with the software for process planning and control. The systems are such that entry-level machines can be purchased and a system can be built from a basic level. The introduction of students into the workplace may be possible in Australia at a level higher than apprentice.

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International Specialised Skills Institute

Since 1990, ISS Institute, an independent, national, innovative organisation, has provided opportunities for Australian industry and commerce, learning institutions and public authorities to gain best-in-the-world skills and experience in traditional and leading-edge technology, design, innovation and management.

ISS Institute offers a broad array of services to upgrade Australia's capabilities in areas that lead to commercial and industrial capacity and, in turn, return direct benefits to Australia's metropolitan, rural and regional businesses and communities. Our core service lines are identifying capabilities (knowledge, skills and insights) to fill skill gaps (skill deficiencies), which are not available in accredited university or TAFE courses; acquiring those capabilities from overseas (Overseas Skills Acquisition Plan - Fellowship Program); then placing those capabilities into firms, industry and commerce, learning institutions and public authorities through the ISS Research Institute.

Skill Deficiency

This is where a demand for labour has not been recognised and where accredited courses are not available through Australian higher education institutions. This demand is met where skills and knowledge are acquired on-the-job, gleaned from published material, or from working and/or study overseas. This is the key area targeted by ISS Institute.

Overseas Skills Acquisition Plan - Fellowship Program

Importantly, fellows must pass on what they have learnt through a report and ISS Institute education and training activities and events such as workshops, lectures, seminars, forums, demonstrations, showcases and conferences. The activities place these capabilities, plus insights (attitudinal change), into the minds and hands of those that use them - trades and professional people alike - the multiplier effect.

ISS Research Institute

At ISS Institute we have significant human capital resources. We draw upon our staff, industry partners, specialists in their field and Fellows, here and around the world. Based on our experience and acute insights gained over the past fifteen years, we have demonstrated our capabilities in identifying and filling skill deficiencies and delivering practical solutions.

Our holistic approach takes us to working across occupations and industry sectors and building bridges along the way:

- ◆ Filling skill deficiencies and skill shortages.
- ◆ Valuing the trades as equal, but different to professional disciplines.
- ◆ Using 'design' as a critical factor in all aspects of work.
- ◆ Working in collaboration and enhancing communication (trades and professional).

- ◆ Learning from the past and other contemporary cultures, then transposing those skills, knowledge and insights, where appropriate, into today's businesses.

The result has been highly effective in the creation of new business, the development of existing business and the return of lost skills and knowledge to our workforce, thus creating jobs.

We have no vested interest other than to see Australian talent flourish and, in turn, business succeed in local and global markets. Carolynne Bourne AM, ISS Institute's CEO formula is "skills + knowledge + good design + innovation + collaboration = competitive edge * good business".

Individuals gain; industry and business gain; the Australian community gains economically, educationally and culturally.

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The Australian Context, an overview of CNC processing in the Australian furniture industry.

Homag Australia¹ (CNC machinery supplier) recently advised that, “Ninety percent of CNC processing centres sold in Australia are three-axis machines. A three-axis machine has three simultaneous NC controlled movements. Of the remaining, nine out of ten machines are sold with only a sawing option as the fourth axis.” A three-axis machine will be capable of drilling in the vertical and horizontal planes (5 faces of the piece), performing saw cuts in one and possibly two directions, and moulding or edge profiling using circular rotating cutting tools selected primarily from a tool magazine.

Australia is (per capita) reported to be one of the largest users of CNC machinery in the world². High-technology machinery in Australia is generally of the following machine types. CNC beam (pressure) panel saws; CNC routing machines; CNC processing centres; “low-cost” flat-bed NC routers; NC moulding machines; PC controlled edge processing machines and other programmable machines including wide belt sanders and shaping machinery. The two main types of solid wood CNC processing machinery are the CNC router and the CNC processing centre. While the CNC router is arguably more suited to the working of solid wood, the CNC processing centre is the more popular machine due to its lower purchase cost and perceived ease of programming. Recently, the low-cost NC router using a flat table, tool change and light-construction overhead gantry system is gaining popularity due to its favorable pricing.

Before the results of this study can be fully appreciated and implemented, an understanding of the current technical position of the Australian Furniture Industry is essential. To this end the report “Analysis of current production practices” (May 2001) was studied. The Furnishing Industry Association of Australia (FIAA) and the Department of Industry, Science and Resources (DISR) commissioned this report. Dr. John Mo, Mr. Stuart Woodman, Mr. Sean O’Brien, Dr. Laszlo Nemes and Mr. Brian Scudds of CSIRO Manufacturing and infrastructure Technology conducted the study. Their report identifies the high-technology production issues that affect the Australian Furniture Industry as follows:

1. Unsatisfactory use of computer systems and CNC equipment.
2. Piecemeal use of technology.
3. Lack of knowledge of CNC use and application
4. Poor training regimes.
5. The use of trade practices instead of production practices.

This extensive National report found that the industry perception is that CNC machinery is good for batches of 50 or more, or repeat orders. This perception

¹ Homag Australia, 9 Ormsby place, Wetherill Park NSW 2164

² Source: Allwood machinery company (machinery suppliers)

prevents further exploitation of technology. Machine set up times are also interesting in that it takes an average 9.4 minutes to set up a basic machine and 9.0 minutes (average) to set up a CNC machine. There appears to be minimal reduction in set-up times due to technology in the Australian furniture industry.

Consultation with suppliers, trainers and manufacturers has identified the following issues: CNC machinery is often purchased mainly to replace current hand-fed production equipment. In addition, price and a sales relationship are often determining factors when it comes to the final decision on the technology to purchase. In many cases, purchases are made without the use of consultants or fully exploring the available market in CNC equipment and software. In most cases there is little planning as to the future manufacturing needs of the machine shop. Components considered “too difficult” are usually retained on existing machinery so that often no additional floor space is achieved by the disposal of “obsolete” equipment.

Some investment is made on CAD-CAM software to assist in the development and programming of prototypes and component parts, but this is often supplied with the machine and is not always compatible with other software used by the company. There is often no difference between manufacturing techniques used on basic and/or CNC machinery. In many cases manufacturers spend little additional funds on tooling (cutters) or jiggging to fully achieve the potential of CNC machinery. Standard cutting tools are used extensively on CNC machines. Screws and staples are often used to hold product to the worktable. Furniture making is carried out by small business and employees are required to wear many hats. The various areas of furniture making should be carried out by specialists, yet by necessity are undertaken by few persons. The need for information and up to date skills is greater than ever. The production of wooden components on CNC machinery is carried out on an ad-hoc basis. Advice on manufacturing techniques and training regimes is essential to promote a viable high technology design and manufacturing culture. “CNC woodworking technology (and related CAD/CAM software) is shaping up to be as influential to wood product manufacturing as the Internet is to free communication” (VCR [Value and Created Resources] E-Journal, Canada).

Australian furnishing manufacturing processes are generally not highly automated with the result that factories cannot produce a large range and number of furniture designs whilst still allowing for relatively small orders. Small batch sizes are important in maintaining a good cash flow in the furniture industry. In addition, a prompt delivery time is one factor that will stand a company in good stead against imported product.

Australian CNC furniture manufacturing often functions at a low level of competence while higher skill levels could combat imported products that currently dominate the marketplace. Chinese manufacturers currently use CNC technologies. For Australia to compete, we must be smarter. This can only be achieved through a continual skills improvement through TAFE, ISS

and other organisations such as teacher advisory groups. It is important that we investigate the ways people develop from operators into technicians.

Quality systems

TAFE and Industry is not widely skilled in the implementation of quality systems in a CNC environment even though quality control and flexibility are the prime consideration for most manufacturers. Quality control is about the entire production process, not just about sanding the end product. Advances in tooling and application of correct cutting data through CNC software should enable a manufacturer to dispense with finish sanding and repair of product. Dwindling timber resources produce a need for better skills in the recovery and reuse of as much “waste” material as possible. Combining of jobs and running multiple parts will reduce the power consumption of an enterprise and reduce the requirement for pre-cutting. Waste is not just about what is thrown in the bin.

CNC training

It is evident that a significant change in the Furnishing Training Package was the introduction of Computer Aided Manufacturing and Computer Numeric Controlled machining into the furnishing curriculum. After discussions between providers, it soon became evident that there was a disparity in skills and knowledge and a variety of standards and machines currently positioned in training facilities around Australia.

Current CNC training is based on actually using the CNC machinery. Suppliers of CNC equipment provide short two to three day training based on specific machine types. This basic training is also provided to TAFE teachers on purchase of CNC equipment. Put simply, operators (or teachers) are shown which buttons to press. There is little focus on manufacturing using CNC technologies. Operators are chosen from the existing workforce and given basic training by the machine supplier, usually on a “need to know” basis. Some manufacturers make use of training provided by TAFE Institutes, often on different brands of machinery. In TAFE, some training at Holmesglen focuses on manufacturing. This is provided to industry during three-hour evening classes conducted over a ten-week period (80 hours). These courses are very popular, and there exists a waiting list to attend these courses. Clearly there is a recognised demand for training above the basic operation of equipment.

Apart from TAFE there is little technical training available for Industry. Traveling overseas to the machine manufacturer will only provide the same level of training as that provided by the local supplier. There are no texts on CNC manufacturing that are suitable for Australian use. Ken Susnjara (1998 and 2000) in the United States wrote the only recognised wood working CNC texts and these relate in the main to nested-based manufacturing. Some text is available in trade magazines but this is provided mainly by machine suppliers and is in the main sales-oriented. Philip Ashley (fellow) is one of

very few regular writers of CNC articles with a series appearing in Australasian Supplier magazine.

Real gains in productivity can be made with innovation in product design, tooling, jig (template) design and optimisation of processes. Unskilled employees will be unable to affect any single one of these issues. In addition, the emergence of high-speed cutting technologies to spindle speeds of up to 40,000rpm will have a significant impact on the industry in coming years. Training is absolutely vital to prevent serious mishaps resulting in horrific accidents from cutting tools rotating at these enormous speeds.

The Diploma of furnishing technology and advanced diploma of furnishing management contain units that include CNC technologies but are currently void of content. There also exists a lack of suitable trainers to deliver these skills to the industry. It is vital that we source or educate motivated trainers to deliver these high-end training units. A description of these units follows.

- LMFFT4003A Organise production processes.
- LMFFT4005A Install and commission CNC software.
- LMFFT5002A Establish and develop production processes and area layouts.
- LMFFT5003A Manage installation and commissioning of equipment.
- LMFFT5010A Optimise CNC operations.
- LMFFT5011A Develop, trial and evaluate prototypes.

All six of these units contain learning using CNC machinery or revolve around CNC technologies. All six require some attention to content and delivery methodology. While the trades are the “backbone of our nation” higher education will play an important role in ensuring that furniture making in Australia does not slip into oblivion.

The establishment of partnerships between training organisations and industry is limited even though this facilitates successful manufacturing processes and allows for the sharing of skills and experience. There is still the perception that “*those who can, do and those who can’t, teach.*” Manufacturers often believe they know it all, but in fact know only what they have been exposed to, or have stumbled across. On the other hand, trainers need real world CNC manufacturing experiences that will allow them to present meaningful CNC training.

The “effective” adoption of highly sophisticated technology into the furnishing industry is limited, even though this is seen to be an effective means of combating the increased levels of external competition. In most cases a low-cost machine is installed in the belief that any CNC machine will affect the bottom line. Very few companies will invest more to obtain equipment that will make a difference. Training is needed in machine specifications and benefits.

Training programs currently deliver individual skills and discipline based skills but should be providing training programs that cater for entire projects similar to industrial situations. The new training package requires students to practice CNC manufacturing in a simulated industrial situation. This requires the satisfactory completion of a number of units related to CNC manufacturing, including communications; plan reading and documentation, several CNC machine types and software.

Australia fails to attract appropriate personnel into the furniture industry. It is important that we understand the training and learning culture exhibited overseas and implement ways to attract more motivated young people away from the “glamour” jobs and back into manufacturing. This can be achieved with a closer relationship with the secondary school system. Australia has an aging population and training should be provided for existing employees with little or no CNC experience.

The craft-based training culture existing in TAFE Institutes needs to be supplemented by a production based training culture. While the crafts must be maintained, a shift to production based manufacture is essential if the industry is to prosper. In addition, there is a possibility of CNC machinery being used in the craft area to reproduce rare and complex mouldings currently being produced as a one-off.

There is a disparity in CNC skills and knowledge and a variety of standards and machines currently positioned in training facilities. While this may be unavoidable, we believe it is possible to teach a generic program on any machine type. What is required are the skills and knowledge to teach the subject while covering the basic principles used on all CNC machine types. Industry’s knowledge of CNC manufacturing technologies is generally based on a need-to-know basis, rather than an educational basis. Waiting lists at Holmesglen Institute suggest there is a real need for advanced training beyond that provided by the machine supplier. A machine technician normally does the training provided by suppliers, and this person has little or no teaching skills.

There is limited knowledge in emerging CNC technologies such as high-speed-cutting. TAFE trainers must keep up to date on this and other emerging technologies. There are limited skills in efficiency in CNC manufacturing through innovative use of cutting tools, small batch sizes and job fixturing and problem solving using CAD, CAM and CIM solutions. Any company would benefit from advanced training in these areas.

Manufacturing design

There is currently limited “design and manufacturing” skills present in the industry and more importantly, the training sector. Design in manufacturing refers to the design of the workplace, the design of the product and the design and problem solving of manufacturing solutions used to affect the manufacture of the product. It should include recycling and landfill but very

often does not. Training programs need to equip graduates and managers with the correct skills in modern production techniques, equipment and design. Crafts persons and artisans make most new designs as a one-off job lot; designers would do well to consider CNC manufacturing while the product is still in the design stage.

Organisations that have an impact on the industry (Victoria)

- Manufacturing Skills Australia
- Furnishing Industry Association (vic/tas) of Australia (FIAA)
- International Specialised Skills (ISS)
- RMIT University
- Holmesglen Institute of TAFE
- FURNTAG (Furnishing Teachers Advisory Group)
- CAMTAG (Computer Aided Manufacturing, Teachers Advisory Group)

Aims of the Fellowship

The aim of this study was to set up a viable community of practice around the need for all registered training organisations to research CNC manufacturing techniques and deliver training in CNC manufacturing as part of the new Furnishing Training Package. It is proposed this study will assist in establishing national linkages throughout Australia with training providers; establish parity of skills and knowledge due to the variety of standards and machines currently positioned in training facilities. It will also lead to new resources and assessment methodologies for the training requirements under the new Furnishing Training Package's certificates 3,4, and 5.

The aims of this study are closely aligned with the National Training Advisory Board's (ALIMTAB) training needs over the next 5 years. "It is that the transformation of this key industry and its change processes are supported by appropriate skill development initiatives. The introduction of new technologies and the vertical integration of processes through all stages of production to distribution will impact the training required driving new approaches and flexible responses (Taken from the Industry Trends and Training needs in the light manufacturing industry. Performance Growth Pty. Ltd. produced this plan for and with assistance of Australian Light Industry Manufacturing Training Advisory Board).

This study also closely aligns with Minister Lynne Kosky's "Knowledge and skills for the innovation economy" document produced in 2002, as well as the FIAA's Response to the Federal Governments Furniture Action Agenda. Both documents clearly call for the uptake of technology to enable increased production efficiency and the use of technology in the development of innovative solution to the changing global economy.

Implementation

- CAMTAG (Computer Aided Manufacturing, Teachers Advisory Group) will be instrumental in overseeing the dissemination of skills and information to registered training organisations through its mentor network (see following diagram).
- FURNTAG ensured that the outcomes of the study were presented to the National Furnishing Teachers conference in 2005. This will be in the form of an official presentation / paper and may include workshops.
- The study outcomes will be presented in the trade media.
- Workshops and seminars organised by ISS.

CAMTAG is subsidiary to the nationally recognised FURNTAG (Furniture Teachers Advisory Group) teacher organisation. Philip Ashley is chairperson of CAMTAG. Bryon Stanley is chairperson of FURNTAG and all four applicants are actively involved with both groups. CAMTAG will be active in multiplying the benefits of this study tour and building CNC training depth, driving new and innovative projects. This is a real project with real outcomes

and benefits. CNC technology creates an expansive learning environment and knowledge is currently limited to a few individuals. The proposed mentoring model is essential to capture and disseminate understanding and skills across the breadth of the VET community and manufacturing enterprises. The following diagram (Figure 1) illustrates the proposed communication pathways and personnel that the ISS study will support.

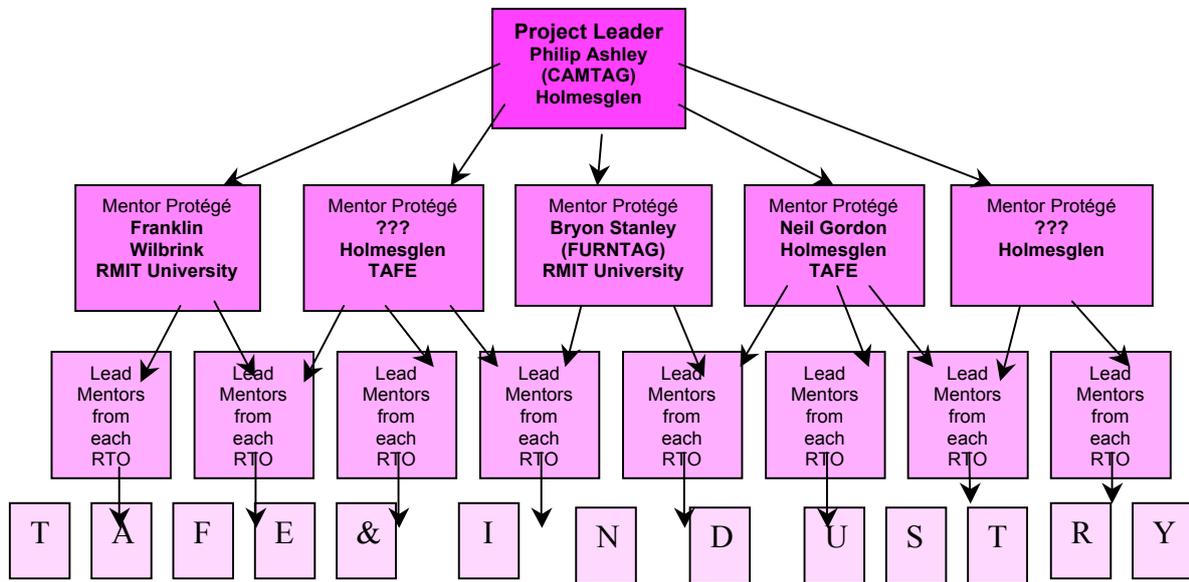


Figure 1 Study communication pathways

The lead organisations involved are Holmesglen Institute of TAFE and RMIT University. The mentor protégés will come from the two RTO's and, with Bryon Stanley and Philip Ashley, will work closely with Industry groups and industry training boards throughout the project.

The loss of key teaching staff due to attrition, retirement or illness will be a serious issue in the coming years. This study aims to eliminate this untenable situation by providing a continual supply of CNC literate teachers able to replace existing ageing staff (**succession planning**). There is also the inability of existing staff to acquire and/or update their skills and experience in the wider global manufacturing community. Simply saying, “this is the way it is” will never substitute for access to the real thing. TAFE’s reputation for excellence and innovation will be enhanced with teaching staff having access and experience in issues related to the wider global situation.

This fellowship gathered information and skills in high-technology furniture manufacturing and knowledge on training delivery in schools, Institutes and industry. “There is increased pressure on using limited resources in a targeted and effective manner.” Australia’s ability to compete on the World market is dependent on materials, technology and a reliable skill base. No one issue can stand alone, each one is interdependent on the other.

ISS and TAFE have an opportunity to lead the industry in CNC manufacturing innovation, design and technical expertise. To the end of 2004 well over one million dollars has been invested in CNC machinery for TAFE Institutes in Victoria alone. Further investments through capital equipment grants and special technology grants will increase this financial commitment. Investments in teacher training in order to effectively use and teach this equipment has been minimal. The current situation is that many TAFE CNC machinery installations are ineffective due to a poor technical understanding and skills in its use. Knowledge and a general awareness of CNC manufacturing regimes in Europe gained by the participants will be disseminated to other TAFE teachers. This will improve the ability of teachers to deliver CNC training in a more international context.

This study is about developing and succession planning for high-tech teachers to teach high-tech machinery and manufacturing processes. The benefits to the four participants have been immediate and will without delay improve student knowledge and skills in CNC manufacturing. CAMTAG has a plan to facilitate the dissemination of knowledge and skills throughout the VET community through an effective mentor network. The benefits to the broader TAFE community over many years are immeasurable. This initiative will satisfy industry's need for effective, motivated CNC operatives able to optimise CNC manufacturing solutions in a diverse industry.

This study will foster the following ideals and Industry benefits:

- Use new CNC technology to become an education partner with regional secondary schools, TAFE institutes, research organisations and universities.
- Assist in establishing and maintaining strategic partnerships with organisations including research and commercial organisations, secondary schools, Industry etc.
- Promote a culture of active vocational education research and development, enhancing the ISS and TAFE's reputation as forward thinking market leaders.
- Continue to develop and enhance partnerships that increase the ISS and TAFE's resource base and allow the pursuit of further growth opportunities.
- Develop a more positive approach to utilising the skills of designers in the CNC manufacturing process to address the impacts associated with low cost imports.
- Develop training programs that focus on waste minimisation, waste management, environment protection, and sustainable CNC manufacturing processes.
- Form effective partnerships with industry to develop furniture-training CNC courses that satisfy industry requirements and covers areas such as product development, quality systems, management training, as well as a range of design subjects and products.

Skills gaps

Furniture design.

CNC manufacturing poses interesting possibilities for designers of furniture. Coupled with modern assembly methods, the production of furniture using CNC technologies, software and modern hardware needs to be investigated. It is important to study the principles of furniture design as applied to CNC manufacturing, and how this is delivered to furniture students in Europe at both apprentice and certificate levels. The installation of a centre of excellence for design and CNC manufacture will be a positive step towards a design culture that is able to work in a modern manufacturing environment.

C.N.C. training regimes.

CNC training in Australia is mainly structured around operating machinery. This study looked at advanced CNC manufacturing and training in European industry and Institutes. It is important to learn how people are recruited into the industry, what is taught and how it is delivered; in particular advanced CNC manufacturing. It is important to learn how training programs equip graduates and managers with the correct skills in modern production techniques, equipment and design. It is important to learn how partnerships between training organisations and industry facilitate successful manufacturing processes and allows for the sharing of skills and experience. It is important to learn how the craft-based training culture existing in TAFE Institutes can to be supplemented by a (CNC) production based training culture.

Part fixturing on C.N.C. machinery.

Part fixturing (jigs and holding devices) are based on traditional methods and often unsuited to CNC manufacturing. It is important to learn advanced and innovative methods of holding multiple parts in a single processing cycle. It is important to learn how cutting forces affect job fixturing on CNC machinery. The application of appropriate tooling is important when holding multiple parts in a single machining cycle. Correct tooling will reduce the tendency of work to “move” during machining. Jig manufacturing is not well understood and this is an area that needs more work and knowledge.

C.N.C. tooling.

Tools (cutters) used on CNC machinery are generally basic in design. Our industry does not understand the cost benefits of appropriate tooling solutions. It is important to learn how to apply CNC tooling on CNC machinery. It is important to learn how to design optimum tooling (tooling magazine) configurations and how to optimise the delivery of the tool to the work piece. It is important to learn how tooling can be used to effect furniture

design. It is important to study tool feed speeds to optimise the productivity of each CNC process.

Design and manufacturing.

There is limited design and manufacturing skills on CNC machining of furniture. It is important to learn how leading European manufacturers have taken leading furniture design and manufacture the components with CNC machinery. It is important to learn how factories are automated to deliver cost-effective goods and how these issues are taught to operatives. It is important to study the manufacturing and design requirements to deliver innovative new designs quickly to the market place. It is important to learn how a large range and number of furniture designs can be manufactured whilst still allowing for relatively small orders.

Quality systems.

Quality control and flexibility are the prime consideration for most manufacturers using CNC equipment. It is important to learn how quality systems are implemented into the CNC manufacturing environment. Lean manufacturing systems in place in European factories have improved output and reduced costs. We would be wise to look at implementing lean manufacturing solutions to create a more competitive workplace and work force.

Waste minimisation.

Dwindling timber resources produce a need for better skills in the recovery and reuse of as much “waste” material as possible. It is important to learn how waste management systems are used in a CNC manufacturing environment and how innovative CNC production methods can improve product recovery, minimise production time and reduce materials waste, especially resource-based.

Emerging technology.

There is extremely limited knowledge of emerging CNC technology. It is important to study the latest trends in high-speed cutting (HSC) technologies. It is important to study and learn about chip removal from the CNC cutting area to improve surface quality and material feed speeds.

Small batch manufacturing.

There are limited skills in efficiency in CNC manufacturing through innovative use of cutting tools, use of software, small batch sizes and job fixturing. It is important to learn the principles of small batch production and look at ways these can be implemented in the Australian context.

Problem solving.

Problem solving using CAD, CAM and CIM solutions are rarely utilised. We will learn how software is used to predict manufacturing outcomes and overcome problems. It is important to learn how automation and CNC manufacturing affects product manufacturing.

Manufacturing design.

There are limited skills in the design of the CNC manufacturing installation. Machinery and software is purchased and installed in a haphazard manner resulting in poor production flow and efficiencies. It is important to study the principles of efficient plant layout and software integration. It is important to learn how bottlenecks caused by CNC machinery are avoided. We will also investigate content for advanced furnishing units LMFFT4003A Organise production processes, LMFFT5010A Optimise CNC operations, LMFFT5011A Develop, trial and evaluate prototypes.

It is intended that this study will introduce the participants to as many of the preceding issues as possible. While it is not feasible to address every matter, knowledge of the issues and the dissemination of appropriate information will make TAFE staff aware and responsive to change and research. If these issues are not dealt with immediately, the Australian Furniture Industry will continue its decline in the World market, further conceding market share to Asian countries, particularly China and Malaysia. Additional jobs will be lost and the Industry will weaken, possibly into a cottage industry.

What is CNC manufacturing?

CNC woodworking machinery is available in many machine types. Solid timber machines include edge-profiling machines such as tenoners, moulding machines and CNC window production lines, and CNC profiling machines such as “point to point” and “routing” machines. Profiling machinery is generally used in the solid timber furniture, stair making, window, and joinery and door sector. In Australia the most used CNC profiling machine is the CNC “point to point” machine, or processing centre and this was the principal machine considered in this study.”

History of CNC wood working machinery

The American Electronics Industries Association describes numerical control (NC) as “A system in which actions are controlled by the direct insertion of numerical data at some point. The system must automatically interpret at least some portion of this data.” The McGraw-Hill multimedia encyclopedia describes CNC as “The method of controlling machines by the application of digital electronic computers and circuitry.” Put simply, NC and CNC are processes where machine functions are controlled by letters, numbers and symbols that the machine interprets as mechanical actions.

NC control came about as a result of the American military aircraft industry. At the end of the Second World War the United States embarked on the development of jet aircraft. It was soon apparent that the faster aircraft required more complex and demanding parts. Conventional means of manufacturing were falling short of the required tolerances and a faster, more accurate method of parts manufacture was needed.

During the late 1940's John Parsons was working on a system where punched cards containing position data controlled a machine tool. The idea was to machine flat templates to check the contour of helicopter blades. Parsons submitted his idea to the U.S. Air Force in 1948 and was awarded a development contract with the University of Massachusetts (MIT) Servo Mechanisms laboratory the following year. During the next three years a conventional milling machine was fitted with positioning servomotors for three axes within the Cartesian co-ordinate system.

The machine demonstrated in 1952 looked very similar to a modern-day single spindle CNC router. Different were the banks of computer consoles needed to drive the servomotors, almost equal in area to the machine itself. All this was driven from a punched paper tape, and became known as Numerical Control, or NC. Computer Numerical Control (CNC) was not to follow until IBM developed the personal computer.

Development in the wood working industries began in the mid 1960's with the first pressure beam saw, and a few years later the Ekstrom Carlson Company offered the first NC router in the USA. The Japanese Heian Company

developed its first NC router in 1968 and in 1969 Shoda claimed the first “circular-cutting” NC router. Early machines of the NC type relied solely on a punched tape. No calculations or modifications were possible. Similarly, early pressure beam saws were set by a series of BCD (binary coded decimal) switches. Every time a new program was needed the switches would be manually set for each cutting pattern. NC routers using punched paper tape would need a new program and hence new tapes if any modifications were needed.

The American Thermwood Company claims the first (Computer) CNC machine, based on the Intel 8080 chip. Unlike NC, a CNC machine is able to perform some calculations such as acceleration and deceleration of the axes, and offer modification of programs at the machine control. These early CNC routers used G-code as a programming language, and this is still used today on all CNC woodworking machines where routing is performed. It is generally not available to the operator but it is still required to control the machine servomotors. A typical modern CNC router is shown in Figure 2.



Figure 2 Modern CNC Router

In the early 1980's the first “point to point” machines appeared. These were primarily drilling machines and were developed from engineering machines of the same type where the workhead rapidly moved from “point to point” to insert pre-programmed drilling patterns. A saw blade was often added but there was no means of simultaneous interpolation of the three axes and therefore no possibility of a routing option. Unfortunately the terminology has stuck and now all machines of similar appearance are (incorrectly) referred to as a “point to point” even though they have evolved from the original concept. These machines are now referred to as machining centres or processing centres. One such machine is shown in Figure 3.

These machines used a proprietary controller and software, and created a situation where programs developed for one machine brand could not be used on another. This has changed and now Windows-based software is used that allows the transfer of programs through generic AutoCAD-format files. This is known as “open-architecture” and compliments the use of Cad Cam software.



Figure 3 CNC processing centre

Advantages of CNC processing

- **Reduced set up times** can be achieved with CNC equipment. A CNC program can be recalled for use within a few seconds. Given that the tools and jigs can be quickly changed, set up time should be reduced to less than five minutes. An additional set up advantage is that **no checks are necessary** after the program has been proved.
- CNC will **eliminate pre-cutting** of components. This will save on tool costs.
- Because CNC tools can be set to operate at their optimum feed rate, **tools will last longer**. The fact that a CNC machine will not suffer from fatigue will ensure that the tool will not burn due to reduced operator performance.
- **Cutting accuracy** of one thousandth of a millimeter is an added bonus and the next time the job is run it will be **exactly the same** in specification and quality as the one processed today.
- Machining with spindle moulders and overhead routers mean that complex jigs need to be made and maintained. This requires skilled trades' persons not only to use the machinery, but also to construct the complex jigs. **CNC machinery requires simple jigs** (if at all) and

- these can be used even if the component dimensions are modified. There will also not be a requirement for an extensive jig storage area.
- Because operators are not manually handling the jig and work piece, there is **less operator fatigue** and the workplace features **cleaner working conditions**.
 - There is usually **less capital investment** than for traditional machinery to do the same amount of work. A CNC machine will do the work of five to eight static machines, and require considerably **less floor space**.
 - There will be a **reduction in processing errors**, and as a result, **increased customer confidence** in the product. An advantage that is often overlooked is the reduced handling of components made on CNC machinery. This results in **less damage to parts, fewer stacks of components** and a **quicker production cycle**.
 - A major advantage of CNC machinery is a **reduced inventory**.
 - With CNC it is possible to practice the “**just-in-time**” manufacturing principle. Make it, sell it and move on to the next job. What this means is that **small production runs become more economical**. **Control over production planning** is vital in knowing how much it is costing manufacturers to make the product. **CNC repeatability and consistency** of production can help achieve this.
 - CNC equipment can provide versatile manufacturing options while running **smaller production lots**. An example of this is where **machining operations can be combined** into the one cycle.
 - **Complex parts can be produced** with CNC machining centres. There are numerous examples of parts that cannot be made with traditional woodworking machinery, but can be simply machined using CNC. Carved door panels are one example. Skilled wood carvers are rare in Australia, and while the CNC machine will not provide the “hand-made” look, a very classy carved finish can be achieved. The programming time may be expensive, but once the program has been created, **it is available forever**.

CAD-CAM

Cad-Cam is a more recent development of the CNC technologies. Much of this development takes place due to the demands of the engineering industry but this progress is also relevant to the woodworking sector. Cad-Cam is the integration of the Cad (design or drafting) process with the Cam (manufacture) of the component. A suitable Cad-Cam system should be considered essential when purchasing computerised machinery. In fact, Cad-Cam software is often considered an option and this sadly, limits the potential of CNC equipment.

CAD (computer aided design)

Cad has been used for many years with the Autocad program being the market leader. This program is used by 80% of draughts person’s around the World. Cad systems are generally classified as either 2 or 3 dimensional. A 2D system draws lines on an X-Y plane with no height values. A 3D system allows the user to define elements in three-dimensional space, allowing the

creation of 3D wire-frame models (two and a half dimension), with solid modeling (3 dimension) capabilities.

Cad programs are object based graphics applications and interpret screen images as mathematical constructions that can be readily manipulated. For instance, a drawing entity (line or arc) is described as “a line from a start XY position to an end XY position in a certain colour and on a certain layer”. This is different to painting and photographic software programs such as the paintbrush program supplied with “windows” software. These paintbrush programs generate bitmapped images that use coloured dots much like the pixels on a TV screen. Some bitmapped file types are bmp, pcx, tiff and jpg.

While all cad systems use object oriented data type, the file format can differ. The file format is how the information is encoded, and for compatibility between different cad programs, this encoding is often provided in a neutral format, such as IGES, HPGL (Hewlett Packard graphics language) and the most popular DXF (originated by Autocad, stands for **D**ata **eX**change **F**ormat). A Cad-Cam program which is unable to produce one of these file types will not be able to read files from another program, CAD draftspersons will not be able to send work to a customer who has a different Cad software program.

The Cad program is used mainly for drawings of geometric shapes based on lines and arcs. Possibly the most powerful is the “Autocad” program (or software), which in the full version costs much more than the computer itself, although a very good “light” version is available for less than a thousand dollars. Less expensive “off the shelf” Autocad compatible cad programs such as Intellicad and Turbocad retail for a few hundred dollars. These programs can produce drawings of the intended product three times quicker than with a drawing board. The drawing will be exact in every detail, can be modified to incorporate design changes, and has the possibility of being applied to the manufacture of the product. This is the Cam process.

CAM (computer aided machining or manufacturing)

Cam is relatively new to the woodworking industry, but will become the most important manufacturing tool of future decades. Cad-Cam will become the basic technology for the factories of the future. Cam programs take the Cad drawing to the final stage to plan, manage and control the operations of the factory through direct interface with CNC machinery.

Cad-Cam is today mainly applied through individual machines controlled by task specific software, but the possibility is there to go beyond this narrow application and to control the whole manufacturing process. This is referred to as computer aided manufacturing. With this technology, the process is controlled from the part design stage through the machining of the on the pressure beam saw edge bander and CNC processing centre. Controlling parts through the entire production process is referred to as “Cim” (computer integrated manufacturing).

In the Cam (machining) process, the product parts are processed into machine language that is transferred to CNC machinery as coded tool path information. These codes control the tools and movement of the equipment that in turn produces the components, usually to an accuracy of at least one hundredth of a millimetre. There is minimal operator input at the machine so semi-skilled persons can be used to load the parts onto the machine table and stack them when the process is complete. This eliminates mistakes, and speeds up the setting up of the equipment for a production run. This time is often reduced from hours to minutes, and in some cases even seconds.

Currently, the major use of Cad-Cam in Australia is in the kitchen and cabinet manufacturing industry. Here CAD can be initially used as a sales tool, referred to as a “front-end” system. The sales person sits down with the customer and within the space of half an hour or so a new kitchen or bathroom has been designed in full colour on the computer screen. Views from any angle complete with light and shade, reflections, kitchen utensils and furniture, and even views through open windows are available to entice the customer into a purchase. Recent developments include a virtual-reality walk-through. A front-end system will produce photo realistic pictures and cutting lists, but may not be able to produce any NC machine codes.

A front-end system can be upgraded to a manufacturing aid with the use of an optimising program. A good optimiser will be able to produce detailed cutting lists of all parts required for the job. In addition, a waste percentage, amount of edging required, time to complete and production costs may also be calculated. The optimised cutting patterns can be downloaded to the computer controlled panel saw for immediate processing. Optimising software needs to be purchased from an industry supplier, and is not usually available as a retail product. As the optimiser is an aid to manufacturing, it is in fact a Cam program. There are some front-end Cad programs that offer an optimiser as an option, but they are usually very basic and do not provide many benefits.

The optimiser output can be set for maximum part recovery, which may require the sheet to be turned during cutting. The recovery can alternatively be set for the fastest possible cutting speed, where maximum recovery per sheet is ignored. Either way the costs are accurately established before the customer gives the go-ahead, and production begins. A good optimiser can cost over thirty thousand dollars, but time and material savings, which can be recouped within a few months of purchase, offset this.

After the parts have been cut, the machining information can be applied through a Cad-Cam program supplied by the machine manufacturer. The most common applications in Australia have been the Rovercad and Aspan programs. These are true Cad-Cam applications, howbeit machine specific. This means they were designed with a specific machine brand in mind. These programs are also mainly focused on manufactured board. The parts are drawn on the computer, and the machining processes applied. These processes include drilling, routing and sawing processes, and on recent machinery include edge banding and sanding. The optimised machine codes

are then sent to the machining centre, where modifications can be made. Usually, however, the programs are ready to run and need little if any modification.

For parts manufactured in solid wood, such as solid timber furniture, programs such as "Pathtrace" and "Procam" can be used to produce three-dimensional drawings. A tool path is then generated which is converted into machine code. This process is called "post processing". A Cad drawing from this software can be post processed to run on any CNC machine. The most common standard format is the G code machine language, a universal set of standard linear and circular motion commands that are modified during the post process stage to suit the specific tooling requirements of the machine. Where skilled persons operate these programs, the output of the machine can be doubled!

In addition, digitising or scanning can develop machine code. A digitiser is an electronic tablet available in various standard paper sizes. The part drawing is placed on the tablet and a stylus or puck is used to identify key points on the drawing. Digitising is a quick method of programming parts from a sample drawing or trace. A digitiser can be a handy tool and for around a thousand dollars can offer the manufacturer another programming alternative.

Scanning can be performed with hand held or flat bed scanners, the resulting bitmap image converted into a vector (Cad) image, then edited to smooth out crooked lines and eliminate unwanted ones. Scanning may require a fair amount of time-consuming editing to "clean up" the image. Scanners are used extensively in the sign-writing industry where machine code is sent to flat bed routers that use drag-knives to cut lettering.

A further element of the Cad-Cam process is the ability to schedule the production. This can be done with a job-scheduling program that may cost as little as a few thousand dollars. A calendar shows the schedule for each work centre (machine) in the factory and a summary of the hours required for each job. These programs are difficult to get working properly as they do not allow for any problems or unforeseen circumstances that do arise from time to time. Generally though, the people who use them say that they give a target to work towards, and can be an efficient production aid.

European perspective.

The “perception” of the European furniture industry will vary depending on personal observation, acquaintances, and what persons with vested interests want you to believe. The brief snapshot presented here is therefore derived more from published literature, reports and media, and what Europeans involved in the industry itself has consistently reported. The opinion(s) of training institutes and research centres are considered to be somewhat “independent” and are highly valued. A 2002 Gottstein fellowship report “Improved high value-added furniture manufacturing in Australia using computer numerically controlled (CNC) equipment” by Philip Ashley has been used to provide some background.

A long and successful history can describe the European furniture industry. Museums throughout Europe house many fine pieces and these are now regarded as examples of fine art. Fine designers and craftspersons such as Chippendale, Sheraton and Boulle are universally regarded. In the post-second World War period the demand to re-build Europe drove the building and furniture industries, and mostly local crafts persons made furniture. Many of the World’s leading furniture makers and machinery manufacturers are located in continental Europe.

In the 1960’s an economic boom saw the furniture industry successful primarily in replacing old products. Up until the 1970’s Italians in particular continued to dispose of valuable furniture pieces, replacing them with the latest “fashion”. Mass-production furniture companies prospered, often at the expense of quality and taste. The 1970’s saw a boom in kitchens. The latest electric appliances and a change in lifestyle from small workspaces to entertaining areas saw the introduction of the “American” style kitchen. In the 1980’s the cost of raw materials increased, and many of the furniture companies of the 1960’s had disappeared, replaced with enterprises that were able to adapt to changing market demands. Design, marketing and sponsoring were new tools that made all the difference. Companies specialising in one type of furniture production used improved technology to develop a flexible production based on smaller orders. The 1990’s saw the introduction of regulations in product and machinery. New materials, fittings and manufacturing technology were the driving factors.

The European industry is similar to Australia in that a high percentage of machines are of the three-axis type and are used in industries employing less than twenty persons. Similar also to Australia is the impact of imports from countries with low labour costs, able to supply low-cost product to a consumer market where cost, the latest design and shorter furniture “lifespan” are current issues.

Materials

European furniture features many different materials and there is an increased scarcity of solid wood used for furniture manufacture. Painted and veneered panels, glass, aluminium and other materials are used extensively. Solid timber is often difficult to source locally, especially of consistent high quality. Competition from imports has forced manufacturers to seek out alternative manufacturing opportunities such as kitchen and bathroom manufacture. This is an area that importers have difficulty in supplying due to the very specific “project oriented” nature of the installations. Production based on panel products is (usually) a simpler process and materials supply lead times are much shorter.

The use of solid timber for furniture manufacturing in Europe is diminishing. Solid timber furniture is expensive due to the high cost of the raw material. Where solid timber is used it is always of the highest quality. There is no evidence of knots or any other “feature” in the material. Manufacturers are moving more towards veneer board as the primary material³, with the use of solid edges on panels and tabletops to improve edge life.

Manufacturers use a variety of materials, such as plastic and aluminium in the construction of furniture products. One example is cabinet doors with wood and clear Perspex strips to give depth. Aluminium sections, glass, plastic and other materials are used extensively. No material is considered outside design possibilities. Successful companies are able to identify customer needs, and quickly adapt to the changing marketplace.

Machinery

Woodworking machinery was developed mainly in Germany from the mid-1960s when the major suppliers were established. Italian companies followed some ten years later. While British manufacturers have largely disappeared, machinery is now made in Spain, Scandinavia and some Eastern European countries (due to low cost labour). The introduction of manufactured boards created a need for new machinery and processes and many of the early “craft” skills have gone to artisans or companies fulfilling the needs of niche markets. CNC processing machinery is widely used in Europe to improve production of a range of wooden items in the furniture and related industries. CNC manufacturing provides opportunities to improve flexibility, quality, short delivery times, operator safety and control over the end product.

CNC machinery is used in almost every type of solid wood manufacture. Furniture (tables, chairs, bedroom and lounge), stairs, entry and cabinet doors, joinery and window production are some examples. Companies using CNC range from the largest companies employing 1000 people to small local enterprises with less than ten employees. Some of the largest factories can be found in Germany, Italy and Spain. Here, automated production lines produce furniture using CNC machinery and automated production and assembly systems, manufacturing up to a million (Australian) dollars of product a week.

³ Jose Oliver, AIDIMA, Valencia, Spain.

Quality

Quality is paramount where solid timber was used. Only the best timber is sourced and every effort is used to ensure each piece is used well. European companies often standardise components and edge profiles. Small job lots are common and evident in both small and large companies. CNC machines are used to perform the maximum number of operations in the one cycle. There is much evidence of CNC machine sanding, and efforts made to apply sophisticated tooling to avoid the sanding process (almost) altogether.

The German furniture industry has focused on quality product. It also has a reputation for providing well-trained technicians for the industry. The Italian furniture industry remains a model for other European countries with a well-developed system of sub-contracting components and product development through a close association with designers. It would appear that this model would only succeed in Australia if enterprises were more aware of design as a sales tool, and were able to share manufacturing resources and skills across the industry.

Quality is one of the most important manufacturing considerations, and great lengths are pursued to achieve consistent quality. This extends to strict control of the moisture content. Where the climate requires factory heating it is applied with consideration to the stored materials. While the use of solid wood is diminishing, where it is used it is treated with great care to gain the maximum benefit from every piece.

Software

Software is a major consideration with the purchase of a CNC machine and in many cases is the determining factor. "Open architecture" software is preferred to enable the use of data generated during the design stage to be used as much as possible throughout production. This includes cutting lists, part drawings and specification sheets. CAD drawings are post-processed to machine code, or drawings are saved in a format compatible with the machine CNC system. There is little use of "stand-alone" software.

Software is extensively used in companies with CNC installations. "Open-architecture" programs are used to take the initial CAD drawing through design, manufacturing and assembly. The concept was referred to on one occasion as "fly by wire". Few companies used "stand-alone" software.

Machine down time is always reduced to an absolute minimum. Quick changeovers are achieved through software, documentation, training and appropriate tooling. In addition, some products had been identified as being unsuitable for CNC manufacturing, and are still processed using standard machines.

Training

The training culture in Europe differs from Australia in that persons are more likely to view education and training as a lifelong issue. It is not uncommon to see middle aged students in further training programs. Companies do however find it difficult to attract young people into the trades. Training in German institutes is mostly “theoretical”. The view is that practical training on machines in the trainee’s own company will be taught on-site. Formal “off-the-job” training is more about the “what and why”, rather than the “how”.

Young school leavers seek out more “glamorous” employment and the present skills shortages will reportedly continue. In addition, the ageing workforce will place pressures on manufacturing labour in the near future. The use of CNC machinery is often seen as a means of reducing skilled labour however there is a perceived need for highly skilled “technicians” able to set up complex programs, solve problems and make shop-floor decisions. Germany in particular has a requirement for a joinery or furniture business to employ a “meister” (six months full time course). In large companies around ten percent of employees are skilled to this level.

Staff employed in furniture manufacturing is generally well skilled. Germans in particular have a culture of continuing education and in many companies all employees are regularly evaluated for effectiveness in the workplace. Persons wishing to start their own business are required to hold at least a meister certificate, or to employ a person who has. In Europe, as in Australia, the value of the CNC technology varies with the skills of staff. Persons responsible for the operation of the CNC machine are invariably well trained. This does not always extend to the person feeding wood to the machine.

Apprenticeship systems similar to Australia produce well skilled men and women able to work effectively on all types of equipment and manufacturing processes. In addition, further education in the form of “masters” and other University courses are well supported in most countries. For example, the meister course offered by the Holzfachschule in Bad Wildungen requires six months full time study and costs the equivalent of twelve thousand Australian dollars, yet is highly regarded as a career stepping-stone. Government subsidies are available and these are means-tested.

Much of the training offered in German schools and higher education is theoretical and this was most evident at the University of Applied Sciences at Rosenheim. Practical training is mostly delivered in the workplace. The ratio is 20% practice and 80% theoretical delivery. Seminars are different with 90% practical delivery. Unlike Australia where training has mainly been oriented to practice, high value is placed on an understanding of materials and processes. It’s more focused to the why, rather than how. Weeklong courses in operating safety are well attended.

The training cost in Australia and Germany is the same at approximately \$10 per student contact hour. In Australia advanced courses are mostly part-time but in Germany advanced training courses are often full-time with little possibility of employment during the training. The University of Applied Sciences at Rosenheim is one of the few Institutes that offer fully funded places.

Design

The ageing European population is said to likely affect the retail market. While ageing, the population is growing and the demand for increased housing will be significant. Future housing will, however be smaller because of demands on space, and furnishing these smaller homes will be a challenge to designers. The demand is for furniture to be more functional than visual, multi-purpose and easier to maintain. In particular, furniture as a fashion commodity is having a reduced life expectancy, or shorter replacement cycles for furnishing products. Good design is also used to simplify manufacture and shorten lead-time. Environmental issues are growing in importance, and the furniture industry needs to appear to be environmentally responsible. There has been a deliberate shift in materials usage from solid timber to manufactured boards in recent years. The supply of raw materials is a priority for manufacturers and will continue to be so in the future.

Automation

Flexibility is often an important manufacturing issue. Some large companies have actually removed conveyor systems and replaced them with wheeled trolleys to improve flexibility of manufacture. Job lots are reducing and as few as three or four kitchen doors are considered normal. With these small job lots, trolleys are an ideal solution. Small companies with large amounts of stock are considered unusual.

Larger companies tend to be more automated and have sophisticated computer controlled manufacturing similar to vehicle assembly lines. Smaller companies similar in size to Australian manufacturers will have one or two major pieces of CNC equipment and mostly produce components as required (just in time). Equipment use in Europe is similar to Australia. There are large manufacturers using large-capacity four and five axis machines to process product, but generally, three axis machines are most common, being 75% of the market⁴. Similar to Australia, a fourth axis is normally used to provide a sawing option. These machines are more evident in the production of window components and stair manufacture. Of particular interest is the increased use of robotics to load CNC machinery and this is evident even in smaller companies.

Tooling

⁴ Source: Weeke Bohrsysteme GmbH

Tools (cutters) used on CNC machinery are seen as a vital investment in improving productivity. Tooling costs range from 5% to 30% of machine costs, and in some cases exceed hundreds of thousands of dollars. Where specific profiles are required, the customer contributes to the cost of tooling and maintains exclusivity for a profile for a given time.

The use of carbide-tipped tools is increasing in Europe. High-speed steel tooling was traditionally used for cutting solid wood because of the favorable sharpness angle of 37 degrees. This benefit is now minimal as micro grain/micro finish carbide can now be sharpened to 40 degrees with an edge of one micron. Micro grain has a higher wear resistance that results in smaller damage to cutting edges under normal cutting conditions. However larger grain carbide is recommended when machining wood with foreign particles. Figure 4 provides an estimate of improved tool life for different grades of carbide and finish. Polycrystalline diamond (PCD) tools are used for machining hardwoods, but softwoods contain more defects (knots) and are considered unsuitable for processing with PCD. PCD tools are ten times more efficient in eliminating heat due to friction. The result is less burning of the cut edge. PCD is used at higher spindle speeds to improve edge quality, but not to achieve a higher (material) feed rate.

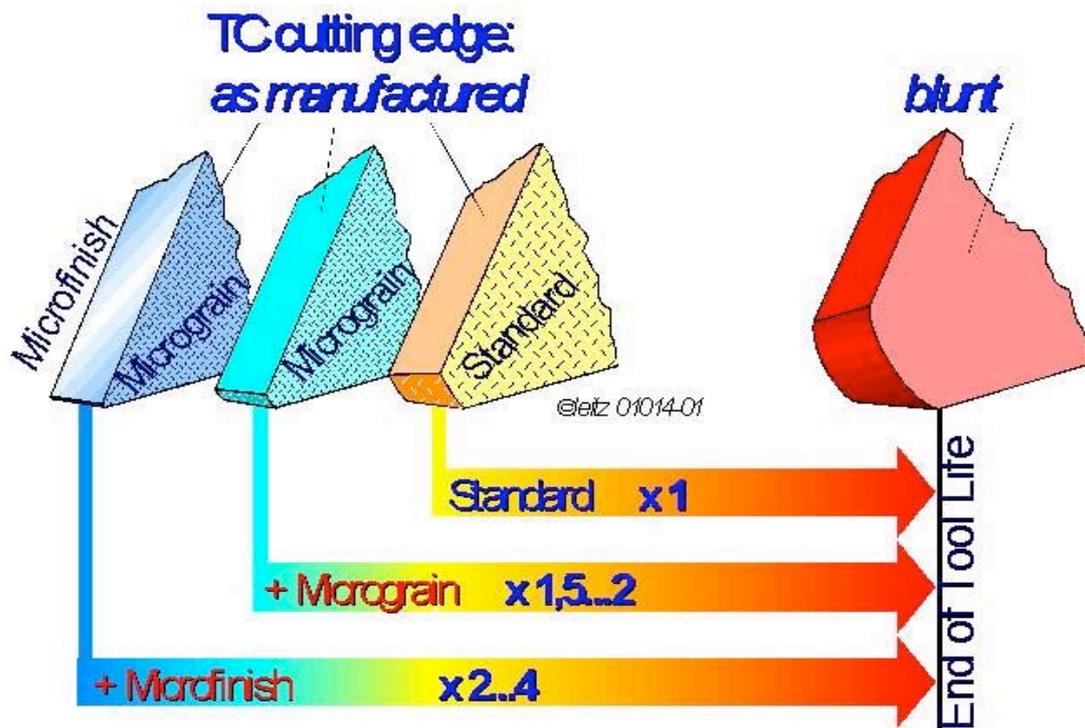


Figure 4 Advantages of micrograin carbide for CNC machining

Due to the (usually) small job lots, flexibility and quick tool changes are crucial factors in tool purchases. On cabinet doors for example, the Leitz “profilcut” system tools (or a similar tool system) is used to provide quick changeover times resulting in more flexible CNC production. The tool management can be handled in-house with little dependence on tool suppliers. “System” tooling is

expensive but because the tool bodies are a one-off purchase, the ensuing production benefits far outweigh the initial tool cost. Where furniture shaping is necessary, many companies standardise profiles as much as possible to reduce the number of profile tools needed. While waste is an issue, the production of off cuts is minimised. This is achieved with tooling capable of “cutting to dust”.

Some of the latest developments in European tooling are focused towards reducing runout. “Runout” is an imbalance of the tool caused by the collet chuck and results in only one of the two cutting edges actually contributing to the quality of the machined surface. This means that optimum tool feed rates are not possible, and lower feed rates used to factor in a quality standard will tend to reduce the life of the cutting edge. Aluminium tool bodies are used to reduce the amount of unbalanced weight in the tool body but the interface of the cutting tool and tool holder (chuck) is where most of the imbalance occurs.

New tool holding technologies such as the Leuco “Tribos” and Leitz “Thermogrip” systems are beneficial in reducing runout to the levels possible with the traditional hydro clamping system. The hierarchy of tool holding systems is as follows (best to worst):

1. Monoblock tool (Tool mounted directly to the spindle interface)
2. Hydro clamp chuck AND Tribos or heat shrink chucks
3. Balanced collet chuck
4. Unbalanced collet chuck (least effective in reducing Runout)

Traditional collet chucks have been tested to a Runout value of $.025\mu\text{m}$. This is 25 million parts of a metre, or 25 thousand parts of a millimetre. Technical advice supplied by the Leuco Company is that $15\mu\text{m}$ runout is the limit for good cutting quality. Hydro and “Thermogrip” type chucks tested to a runout value of $3\mu\text{m}$. However, hydro chucks are three times more expensive than Thermogrip or Tribos type chucks and the feeling is that in time the industry will adopt the new chuck technology to reduce costs. The new chucks are also a slimmer design and have a tendency to improve chip flow (extraction). An example of the new technology tool holders is shown in Figure 5.

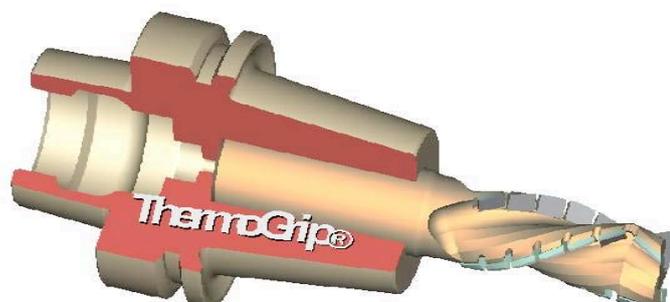


Figure 5 Thermogrip CNC tool holder

High speed cutting

The term “HSC processing” (high speed cutting) originates from the metalworking sector, and refers to the cutting or machining of materials at enhanced (higher) cutting speeds. Current CNC machine spindle speeds are supplied in the order of 18,000rpm to 24,000rpm with 18,000rpm being the most common speed. Improvements in the edge quality of wood furniture components can be achieved by increasing the cutting speed of the tool. The cutting speed refers to the actual speed of the tool edge, not the revolutions per minute of the spindle although a higher RPM will achieve a higher cutting speed.

It is possible to increase the cutting speed of tools by increasing the tool diameter but unfortunately the greater the tool diameter the greater the possibility of unbalance. Increasing tool diameter also means that more teeth are required, as the tooth progression (distance between each cutting tooth) will change. In the woodworking sector today, cutting speeds of up to 80 m/s are achieved when trimming with large diameter profile tools. Knowing this, it is evident that the cutting speed of profile tools in the range of 80mm to 90mm diameter is optimal.

The optimum wood cutting speed range of routing tools is 50 to 80 metres per second and small diameter tools are unable to achieve even the lesser speed. A 25mm cylindrical router cutter has a cutting speed of only 23 m/s or less than half that recommended. The following diagram (Figure 6) demonstrates the peripheral speed produced by various diameter tools operating at various speeds (RPM). It is in the area of small diameter tools that gains in quality and productivity due to greater spindle speeds is most apparent. To achieve optimum performance it is necessary to lift spindle speeds to between 30,000 and 40,000 rpm. The mechanical engineering requirements for HSC processing are a high degree of rigidity in the machine frame, improved axes drives for greater response accuracy, high spindle speed and tools designed for high-speed rotation.

The higher kinetic energy presents some increased risk if tools were to break. Human error in installing the wrong tool and accelerating a large tool to very high speeds will also be a serious risk. Expensive CNC tool management systems using microchips embedded in the tool itself is currently the only sure way of preventing this. Future developments will see torque momentum sensors on the machine spindle.

Homag (machinery), Leitz (tooling), Leuco (tooling), Benz (spindle development), IFW (University Stuttgart), FH Rosenheim (University Rosenheim), Reichert Holztechnik (manufacturing trials) and Wossner (manufacturing trials) have completed a four-year government funded program into high-speed cutting using CNC machines. Recent research includes spindle development, safety, and the removal of waste (chip flow) at high cutting speeds. The German ministry for education, development and research funds the program. When this technology becomes available in

Australia, production of components on CNC machinery can be doubled! The benefits of HSC are that when higher RPM brings the cutting speed to an optimum level, higher feed speeds can be used to reduce the cutting time, increasing material output.

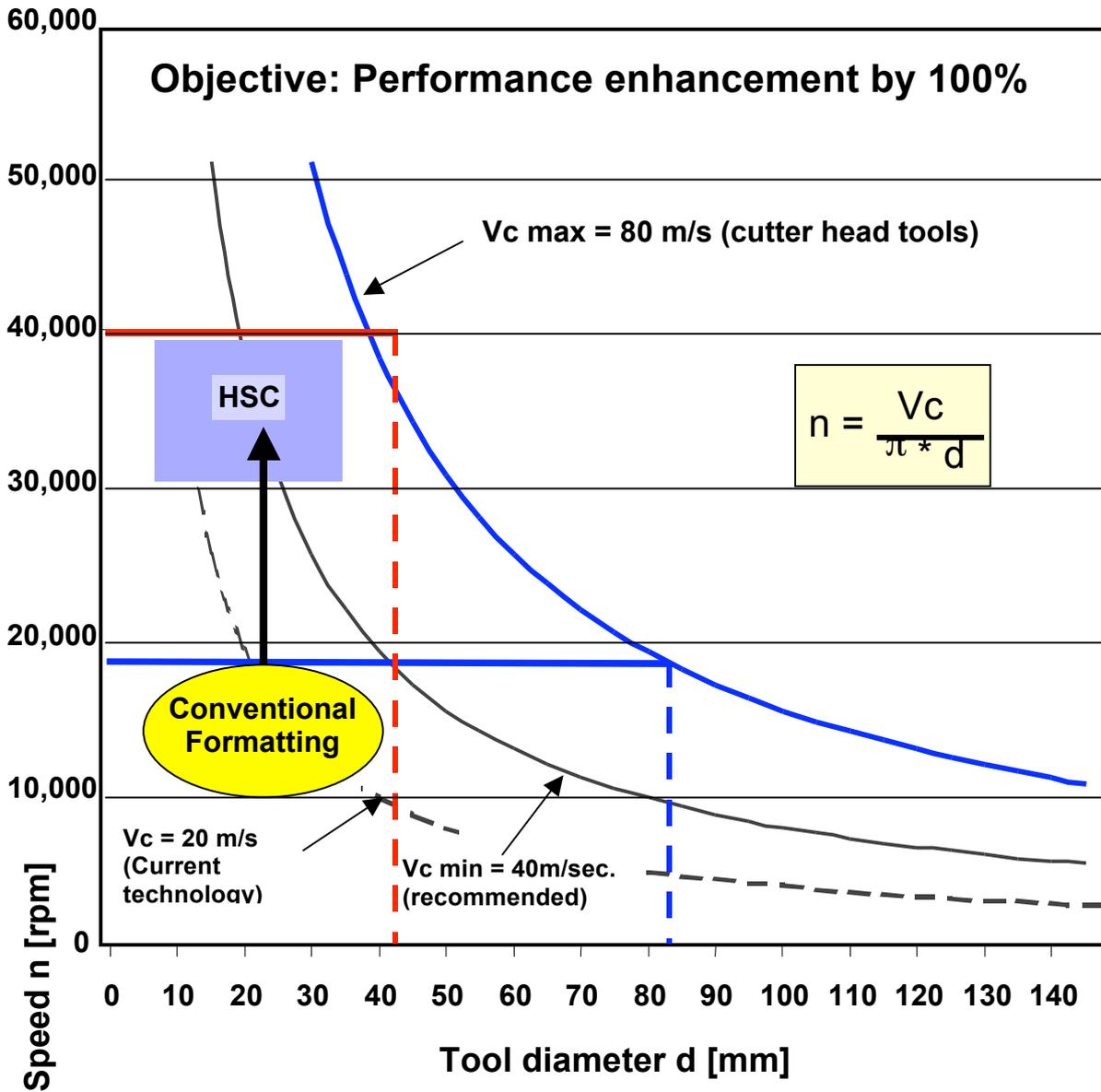


Figure 6 HSC Graph

Fellowship program

The fellowship program sought to answer the questions and acquire skills embedded in the skill gaps as identified earlier. The fellows visited the international Ligna wood working trade fair held every two years in Hannover, Germany. There we met with technical representatives from leading suppliers of CNC machinery, tooling and equipment.

The fellows visited leading furniture and machinery manufacturers, designers and wood workers skilled in the design and implementation of manufacturing solutions using CNC machinery in a targeted and effective manner.

Itinerary

The study tour was organised as follows:

DATE	LOCATION	MORNING		AFTERNOON	
		VISITS	CONTACT	VISITS	CONTACT
30 th April	Travel Melbourne to Germany (Hannover)				
2 nd May	Hannover	Ligna trade fair	Various	Ligna trade fair	Various
3 rd May	Hannover	Ligna trade fair	Various	Ligna trade fair	Various
4 th May	Hannover	Ligna trade fair	Various	Hildesheim Fachschule	Hermann Sielaff
				Weeke CNC factory	Theo Feldmann
5 th May	Hannover	Ligna trade fair	Various	Ligna trade fair	Various
6 th May	Hannover	Ligna trade fair	Various	Ligna trade fair	Various
7-8 May	Travel Germany to Denmark (Odense)				
9 th May	Odense	Danish Technological Institute	Finn Tang Thomsen	University college of engineering	Flemming Ilsoe
10 th May	Odense	Carl Hansen	Knud Erik Hansen	Sauer Danfoss	Finn Tang Thomsen
				Skiolo Mullerup	Finn Tang Thomsen
11 th May	Travel Denmark to Switzerland (Biel)				
12 th May	Biel	Berner Fachhochschule	Andreas Zurbrugg	Stuber	Andreas Zurbrugg
13 th May	Brienz	Fraubrunnen	Christoph Lengacher	Fluck Werke	Andreas Zurbrugg
	Brienz			Schule fur Holzbildhauerei	Andreas Zurbrugg
14 th - 15 th May	Travel Switzerland to Germany (Rosenheim)				
16 th May	Rosenheim	Technical museum, Munich		Rosenheim wood museum	
17 th May	Rosenheim	Fachhochschule	Freider Scholz	Fachhochschule	Rainer Grohmann
18 th May	Rosenheim	Fachhochschule	Freider Scholz	Fachhochschule	Prof. U Paul
19 th May	Travel Germany to Italy (Milan)				
20 th May	Milan	Unifor	Craig Raison	Unifor	Craig Raison
21 - 22 May	Travel to Australia				

Visits

Ligna Plus machinery fair, Hannover, Germany.

According to figures published by the German Engineering Federation (VDMA) Germany remains the World's top producer of wood working machinery with a 2004 turnover of 3.1 billion Euros. The Ligna fair held every two years in the German city of Hannover still remains the World's biggest woodworking fair. In fact this year's fair held during May was reported to be the best show yet. A comprehensive range of events was organised to cater for every facet of the forestry, wood and secondary processing industries using wood as the primary material.

The major exhibitors at Ligna this year were again the Homag, Biesse and SCM groups. The importance of Ligna to the three groups can be seen by the enormous sums invested in the exhibits. Some of the largest companies were reported to have spent in excess of five million Euros (A\$8.5 million). At this year's fair there was an increase in the number of four (Figure 7) and five axis machines on display. In addition, complete working centres where (mostly) panel material was first cut, transported and then re-worked to a finished component, all in the one machine were exhibited. The visit to Ligna was important to provide an overview of CNC technology to the tour participants, as this fair is in reality a "one-stop-shop" for the World's machinery manufacturers.

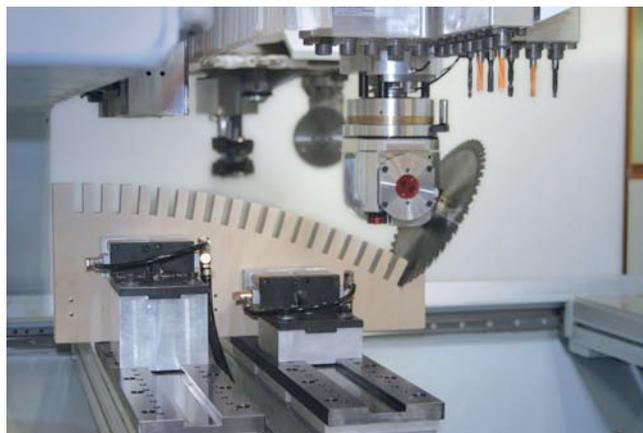


Figure 7 Four and a half axis technology from Homag

In addition to the endless displays of wood working machinery, Ligna Hannover supports presentations in other vibrant categories. An outstanding example was HSB Institute (Biel, Switzerland) demonstrating the ability to weld wood using high-speed vibration technology. The project team is able to "weld" wood up to 150mm in length, attaining adhesive strength within seconds. The high-quality, environmentally friendly product has only one drawback, a dark line due to the intense heat generated by the process. Other innovative new technologies included a new technique for glueless assembly of workpieces where thermoplastic dowels are melted by ultrasound, penetrating into the porous material of the work piece and hardening in seconds (Figure 8).



Figure 8 Thermoplastic dowels used to assemble furniture

An interesting example of CNC technology being used to manufacture affordable household furniture was presented by “Loreley” design. Loreley manufacture with plywood on a basic 3-axis CNC machine and produce tables, chairs and storage units such as shelving and cabinetry. The product can be quickly assembled and uses the materials own spring tension to hold together (Figure 9).



Figure 9 Loreley design using CNC technology

It was interesting to see where all the wood working machinery is heading as this is probably where our next competition is coming from. Eastern Europe is on the move with significant increases in German and Taiwanese machinery purchases. In particular, Turkey shows an increased interest in wood working, as does India, South Korea and Vietnam in Asia.

The key issues from our visit to the Ligna fair were the use of robotic systems to load and unload CNC machinery. This has increased considerably since fellow Philip Ashley was there four years ago. In addition, the use of automated systems has increased and improved. It is now possible to set up a complete CNC line in the one machine. This equipment unstacks, cuts, machines, applies further processes and stacks without human intervention.

The significance for Australia will be if countries such as China start to implement such equipment and can reduce their labour overheads even further, imported goods may be even cheaper and the Chinese may even be capable of delivering “project-based” furniture such as kitchens and office designs into this country at a competitive cost and time frame.

For us as visitors, it was interesting to see the variety of CNC machinery and applications the equipment could be put to. This knowledge has already started to be filtered to TAFE students and Industry through classes conducted at RMIT and Holmesglen, and through the mentor system set up through the CAMTAG organisation.

Fachschule Holztechnik, Hildesheim Germany.

Our visit to the Fachschule Holztechnik in Hildesheim was organised through Mr. Hermann Sielaff of the school. Mr Sielaff was exhibiting at the Ligna fair. The school is one of higher education and interesting in the way design is implemented into the teaching of furniture manufacturing using all types of equipment, inclusive of CNC.



Students complete a project for completion of the course. This project is a complete furniture piece that has been designed by the students themselves. Students work in teams in the design and manufacture of a product that is then “sold” using a website set up for this purpose. A limited number of units are produced and sold in this manner. Students access the workshops at various times during the week and often out of “normal” hours. It is not uncommon to see students sitting around in groups in self-directed sessions.

The facilities at Hildesheim are pleasant, with recent machinery and up to date laboratory equipment. Student’s work partly by their own initiative and a progress board chronicles their progress (or lack of). An example of the facilities and a sample student piece is shown in Figure 10.



Figure 10 Fachschule Hildesheim and student design

Weeke Bohrsysteme GmbH, Gütersloh, Germany.

Weeke Bohrsysteme GmbH is a traditional machine manufacturing company established in 1945. At that time Gustav Weeke & Son founded a locksmith's company in Herzebrock in Westfalia that had the aim to solve the requests of the woodworking companies. Weeke developed the first worldwide lock insertion machine in 1954. The next machine allowed multi-spindle drilling into work panels, eliminating the costly and difficult groove-and spring connecting method that was used up to that date. Since that time, CNC-Technology and chaining with other processing aggregates has become State-of-Art at Weeke. In May 1986 the family-owned company was integrated into the Homag Group. Weeke took over the role in the special range of drilling, routing and assembly technology for lower-cost processing.

Weeke is typical of most European manufacturers in those sub-suppliers produce basic parts that are re-machined by Weeke prior to assembly. The company is currently developing through-feed panel machinery with the capability of top and end drilling in addition to gluing and dowel insertion to a capacity of eight thousand panels per shift. In the area of CNC processing of timber products the company has a range of machines based mainly on table size. Three axis machines are the largest production volumes, but Mr. Feldmann sees a shift towards four-axis technology.

Since our return, Holmesglen Institute has placed an order for a four and a half axis machine from this company; to be situated in a specialist CNC design centre at Holmesglen's Integrated Manufacturing Cell.

The benefit of visiting a Machine manufacturer was the ability to see first-hand the construction of CNC equipment.

Danish Technological Institute, Odense, Denmark.

Danish Technological Institute occupies a crucial position at the point where research, business, and the community converge. The Institute's mission is to promote growth by improving interaction and encourage synergy between these three areas. The Institute is located at six premises throughout Denmark. Our visit was to the facility located at Odense in central Denmark.

The Institute was founded as an independent institution in 1906 and is one of the oldest of its type in the world. The Institute now has almost 850 employees, making it one of the world's largest private institutes to supply approved technological services such as consultancy, tests, certification and training for companies and public-sector organisations. Danish Technological Institute is an independent, not-for-profit institution approved by the Danish authorities to provide technological services to business and the community. The Institute employs experts in hundreds of different fields at 40 centres organised under the auspices of the 6 organisational units that define the main parameters for their work:

- ◆ Building Technology
- ◆ Industry and Energy
- ◆ Informatics
- ◆ Materials
- ◆ Productivity and Logistics
- ◆ Industrial Development

The Institute adopts an interdisciplinary approach to innovation and to the task of improving the ability of small and medium-sized companies to exploit new technologies and management tools. Customer activities and close cooperation with a wide range of enterprises account for the majority of the Institute's turnover. The Institute has a turnover of some Euro 83 million and is financially sound.

The Ministry of Science Technology and Innovation invests some Euro 15 million per annum in the Institute's R&D activities and the dissemination of R&D results. These funds are supplemented by the significant sums that the Institute contributes to self-financed joint development activities and investments in equipment. Around 10% of the Institute's turnover stems from activities abroad, and healthy relationships have been established with R&D departments in Europe, North America and the rest of the world.

International Activities

Danish Technological Institute is active in a wide range of international projects and has a significant international network. This means that new knowledge and technology are exchanged on a running basis. By working internationally the Institute ensures an international level of experience in their business areas - for the benefit of Danish and international customers.

The Institute participates in international programs under the auspices of the EU, the UN and a variety of other national and international organisations. In recent years, the Institute has been particularly active in Eastern Europe.

The objective of the Institute is to generate value for its target groups by making the best possible use of knowledge available anywhere in the world. A precondition for all of the Institute's activities is that they must generate improvements and growth.

Danish Technological Institute wants to be Danish companies preferred supplier of technical and managerial service in our core competences and a recognised partner within neighbouring international markets.

Mission

Danish Technological Institute aspires to be:

- ◆ The main service institute to Danish SME's
- ◆ An important supplier of specialist know-how - also to large companies
- ◆ A dynamic developer and mediator of new technological know-how to innovative Danish companies
- ◆ A recognised service supplier in the Northern and Eastern European markets
- ◆ An attractive partner to research centres, organisations, institutions and public authorities as well as private consultants
- ◆ An important bridge to the newest national and international knowledge

Characterised by services, that promote:

- ◆ Innovation and competitiveness
- ◆ Learning and qualification
- ◆ Sustainable use of resources
- ◆ Cost effectiveness

"Knowledge that works"

Danish Technological Institute is an independent, non-profit institution recognised as an approved technological service institute according to the Law on Technological Service. Her Majesty Queen Margrethe II of Denmark is patroness of Danish Technological Institute.

(The preceding text was provided during our visit and is available on the website at www.danishtechnology.dk)

Denmark has few natural resources. What they lack in resources is made up for in know-how. The country has a high level of appreciation for training and knowledge. Unlike Australia, it is almost impossible to get a job in a trade area without a qualification. A high level of co-operation exists between their TAFE equivalent and Industry and we found evidence in this in the industrial release and project programs we visited at Skiolo and Sauer Danfoss. In Denmark, Industry values qualifications and foster high levels of skills. Students are provided with substantial income support while training. A high staff to student ratio also assists with good training regimes. Their pre-apprenticeship

programs differ to Australia in that the students do a range of subjects that enable them to choose different career options at the completion of the course. There exists the means for students to leave and re-enter the education system. Young people are well catered for educationally. The country supports this with higher taxes, but the public sees where this is being used and accepts this.



Mr Finn Tang Thomsen of the Institute was instrumental in organising all our visits in Odense, Denmark. There were no facilities at this location.

Odense University College of Engineering, Odense, Denmark.

Odense University College of Engineering was founded in 1905 as the first of its kind in Denmark. Since then it has developed into a fully comprehensive and advanced university of applied sciences offering B.Eng. and M.Sc. degrees in engineering.

The University participates in several international educational programmes and organisations, including the European Society for Engineering Education.

Odense University College of Engineering offers eight courses (3 1/2 years each) leading to a Bachelor of Engineering degree (B.Eng.):

- ◆ Chemical, Biochemical and Environmental Engineering
- ◆ Civil Engineering
- ◆ Electrical, Electronic and Computer Engineering
- ◆ Global Management and Manufacturing
- ◆ Information and Communication Technology
- ◆ Integrated Design
- ◆ Manufacturing and Management
- ◆ Mechanical Engineering

They work in close cooperation with the University of Southern Denmark in providing six courses (5 years each) leading to a Master of Science degree in Engineering (M.Sc.):

- ◆ Chemistry
- ◆ Physics and Technology
- ◆ Environmental Engineering
- ◆ Computer Systems Engineering
- ◆ Structural Engineering
- ◆ Product Development and Innovation

(The preceding text was provided during our visit and is available on the website at www.ouc.dk)

The University focuses on industry co-operation, problem based learning and internationalisation. The University believes that a high level of student involvement, application of knowledge and real-life experiences make better engineers. The University is actively involved in the “Robocluster” group and this technology is likely to have a major impact on manufacturing in Denmark. We saw evidence of an increased use of robotics throughout our trip.

The University’s one-year robotics course covers the following:

- ◆ Problem-solving, building a robot
- ◆ Project management and teamwork
- ◆ Evaluation of technical, business and political aspects
- ◆ Basic C programming of embedded (robotic) systems
- ◆ Robotic controller architecture
- ◆ Industrial automated engineering

◆ Sensor and actuator technologies

The University has extensive workshops and machine shops and students build and program robots for various applications. Figure 11 shows a track laid out on the floor that a robot is “trained” to follow. This is a basic step in the education of these young people. Also shown is a picture of the wooden ruler production line. This very basic layout is used to teach students the relationship between manufacturing stations and leads to the concepts of lean manufacturing where each manufacturing station is designed to fit into the flow of the entire line.



Figure 11 Ruler assembly line and robot track

The key issues at the Odense University College of Engineering was the robotics program and the training of students in lean manufacturing (including release to industry for project work).

Carl Hansen and Son, Aarup, Denmark.

There are many classic chair designs. Gerrit Thomas Rietveld (1888-1964) designed the famous red and blue and Zig Zag chairs. They may not be very comfortable to sit on, but these recognisable designs will last forever. Arne Jacobsen designed the Egg Chair, one of the most influential post-war furniture designs and the ant chair (1951) for Fritz Hansen, a commercial chair manufacturer based in Denmark. The ant chair is familiar in restaurants, public halls and other high-density seating situations.

Carl Hansen (no relation to Fritz) specialises in classic design chairs by Hans J Wegner. Carl Hansen has been making Wegner's designs since 1949 when the wishbone chair (CH-24) went into production with a woven fibre seat. Other designs include the CH-07 (shell chair) a three-legged chair designed in 1963 featuring a lacquered bent plywood frame with wool seat elements. The "shell" chair sells for around \$2,000 each! The stackable CH-20 ("elbow chair"-1956) is one of the most difficult chairs to manufacture but this has been achieved by technology (Figure 12). Carl Hansen also produce a number of other classic Wegner chair and table designs that are exhibited at The Museum of Modern Art in New York. Carl Hansen is a company built on quality, technology and relationships; but most of all, design.

Hans J Wegner

Hans J Wegner trained as a cabinet-maker before attending the Copenhagen School of Arts and Crafts, where he later lectured from 1946 to 1953. From 1938 to 1942, he worked as a furniture designer in Arne Jacobsen and Erik Moller's architectural workshops. 1943 saw him set up his own studio in Gentofte where he worked with Borge Mogensen in the design of an apartment shown at the 1946 Cabinetmakers Exhibition in Copenhagen. Inspired by classical portraits of Danish merchants sitting in Ming chairs, one of his first chair designs was the 'Chinese' chair and this would provide the basis for many of his later chair designs. Wegner created a series of chair designs that helped establish Denmark as an international leader of modern design. The Wishbone Chair (CH-24) is widely considered to be his most successful of the series.

Wegner is one of the principals of 'Danish Modern' furniture. His designs were intended to stand on their own merit, and not necessarily form part of a set. He has a deep understanding of furniture for everyday life, his designs characterised by a dedication to practicality and comfort. His furniture is not only artistic and beautiful but also practical. Wegner said, "Many foreigners have asked me how we made the Danish style, and I've answered that it was rather a continuous process of purification, and for me of simplification, to cut down to the simplest possible elements of four legs, a seat and combined top rail and arm rest." Wegner's preferred method of working was to start with a sketch from which he would make a 1:5 scale model followed by a full-scale prototype. Before beginning production, each piece of furniture was drawn at full scale on a single sheet with the drawings - two elevations and a plan view,

superimposed on one another. Wegner says, “A chair should allow freedom of movement and accommodate more than one sitting position”.



Figure 12 Elbow chair by Hans Wegner

Throughout his long career, he has designed furniture extensively for Johannes, Carl and Fritz Hansen. His furniture includes cabinets, tables and other works, but his (almost) 200 chairs are what he is most remembered for including more recently, airport seating. Wegner and other famous architects and designers are all around the same age and in their heyday, inspired each other to competition and excellence. Hans always looked to a new design each year. For his work, the Royal Society of Arts, London made him an Honorary Doctor in 1959. In 1992 he handed over his design studio to his daughter Marianne who continues to look after his designs and follow in his footsteps. Hans Wegner celebrated his 91st birthday on April 2nd 2005 and still receives a royalty for every chair produced.

The factory

Finn Tang Thomsen of the Danish Institute of Technology introduced us to director Knud Erik Hansen, the director of Carl Hansen and Son. The company is 100 years old, and is Located in Aarup near Odense in Central Denmark. The new 6,000 square metre complex was built to create an environment planned to maintain traditional craftsmanship, modern technology and pride in making what may be the most beautiful and sought after chair designs in the World. Nowadays the production is entirely Hans Wegner design and is sold in North America, Japan and throughout Europe. Knud Erik previously managed a bedding factory and bought Carl Hansen and Son from his brother who was not interested in expansion.

While the present factory in Aarup employs all the very latest technology, all products are still made with attention to detail and traditional construction methods by the long-time staff. Oak, Cherry and Walnut timbers are delivered three times a day. The wood is steam bent as required, or machined in four automatic “Zuckermann” copy lathes. All reject timbers are returned to the supplier for credit. Sophisticated five axes CNC machines are used to shape some complex components. Carl Hansen uses CNC machines because low-technology countries are unable to compete against the repeatability and consistent quality. The furniture designs are also very difficult to copy. As an instance, the CH20 chair side, back and front rails are curved and meet at the legs. Designed in 1956, it was believed to be too difficult to manufacture economically until new technology came along.

No mechanical fixing is used on the product and all assembly is done with traditional cabinet making joints such as dowels and mortice and tenons. Some species such as Oak often move during the (glue) drying process so the assemblies are held in specially made clamps until dry (Figure 13). A significant part of the process is in sanding the product and some of this work is done with computerised robots, almost human in their movements, sanding complex shapes on a twenty-four hour a day schedule. Robots are becoming more common in the European furniture industry and Denmark is a World leader in robotic technologies through the Odense University College of engineering’s “Robocluster”. Apart from this, the finishing of the product is often outsourced because this process is very time-consuming. Before sanding, all the parts are soaked in a solution of soap and water to raise the grain; this results in a glossy, smooth finish that is a characteristic of the product. The end of the process is the weaving room. Forty weavers weave only eight chairs a day in a bright, spacious and quiet environment but are penalised if they do more. The quality of finish is too important to risk.

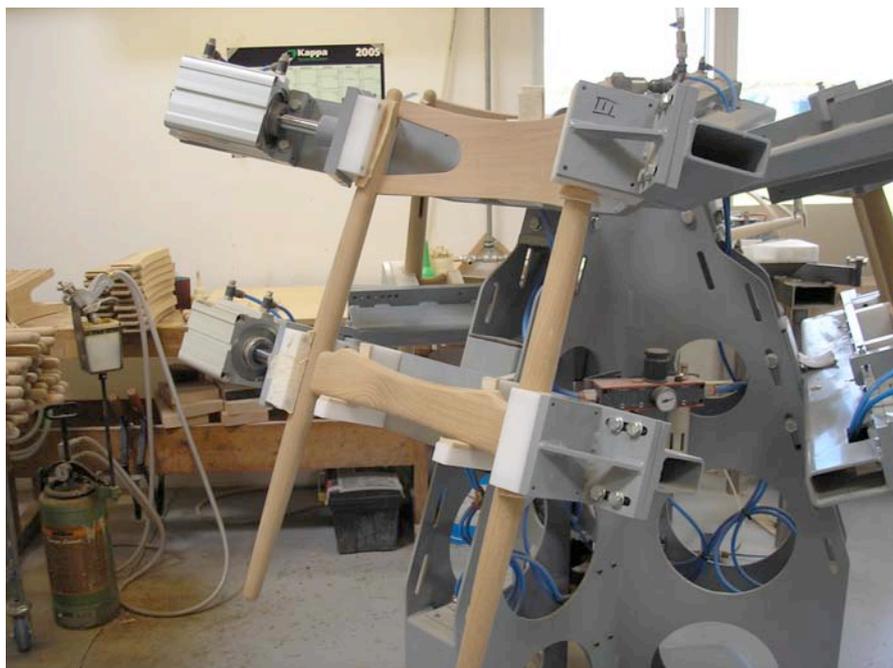


Figure 13 Specially made clamps hold the chair until dry

“The design sells itself” is a lesson for all would-be designers and furniture makers. Drawings from the 1940’s are still used in the modern factory. Recently Marianne Wegner paid a visit to the company to check on the designs. She observed that the CH24 chair back legs were not as her father designed. Pulling out the drawings, Knud Erik asked what the problem was. Marianne produced a drawing with a later date and modifications to the design so production was stopped while alterations were made. Such is the influence of the designer! Marianne is an accomplished furniture designer in her own right and recently designed a table where no person sat near a leg. The table was designed for the lucrative Japanese market but turned out to be too big. No manufacturer can modify Wegner’s designs. This can only be done in consultation with the designer. Minor modifications have been made to some of the chairs for comfort and width. An extreme example is that over the last twenty years Wegners chairs have been raised 20mm due to the population getting taller. And what of the future of furniture design? Knud Erik Hansen said that there are some good designers coming out of Italy that may provide fresh, new and innovative furniture design.

Today, Carl Hansen produce four times the number of chairs they made four years ago. Carl Hansen is 95% in the retail market while the namesake (Republic of) Fritz Hansen is primarily contract and commercial. Knud says that for Carl Hansen, relationships in business lead to new customers. Progress has also been made partly due to the loyalty of their staff that assists in the development of new product, often coming in unpaid over the weekend to develop new processes. The high cost of the product makes efficiency all that more important and plenty of time is devoted to ironing out the wrinkles. Engineers are often employed to look at minor changes to the design and manufacturing process in a continuous improvement schedule. New technology is used to allow the company to expand, lowering costs and maintaining quality. Knud says the company “Does not make much profit per chair but we make a lot of chairs. We have made the same chairs for fifty-four years! We ship worldwide at moisture content of eight percent and have less than one percent breakage. Our future looks good and recently, at the Milan fair we saw current trends are to steel, glass and plastics but we feel that wood is coming back into fashion”. Fashion and good, useful design gives Carl Hanson the winning edge.

The key issues from our visit to Carl Hansen were the company’s ability to manufacture and market very expensive product using CNC machinery and robotic material handling and feeding equipment. As the owner said, “we do not make a lot of money on each chair, but we make a lot of chairs”. The company works closely with well-known designers and produce a high-quality product that is marketed well and much sought after Worldwide.

Sauer-Danfoss

This visit was organised by the Danish technological Institute. The company produces electric motors. What were interesting were the lean manufacturing systems adopted by this company. Any company can adopt lean manufacturing, as the principles remain the same. The company is changing from DC to AC motors and as part of the re-organisation within the production line; lean manufacturing techniques were being implemented. A small group of students from the Danish technological Institute were at the company doing an on-site project that actually assisted the company in its endeavors. The company view the production line as a value chain, and all work is designed to take the same amount of time. Any task that takes longer is shortened so there is no break in the production flow. CNC equipment frees up an operator to participate in another task while the CNC is executing a program. Shift reports look at what is ordered, what is made and cycle times. The report also looks at what have been the problems.

At Sauer-Danfoss we saw a company that had moved to a 'line-oriented' production system. This means that the company has been able to speed up production by reducing the bottlenecks created by the single workstation system used before. If the flow of product stops for any reason there is a problem and no lean manufacture. This type of production may be difficult in a batch manufacturing situation such as furniture making.

Skiolo Mullerup

The visit to Skiolo was organised by the Danish technological Institute. Skiolo manufacture farm machinery. The company had on-site, students from the Danish Technological Institute doing a project on lean manufacturing. Employees are encouraged to give the students ideas for improvement (seems like the old TQM). A project board is used to show every employee what is planned and to keep them informed of the progress. Project board presents well with company logo and uniform look. The students were working on systems to improve the production of a cow-cleaning machine. Part of the equipment is shown in Figure 14.

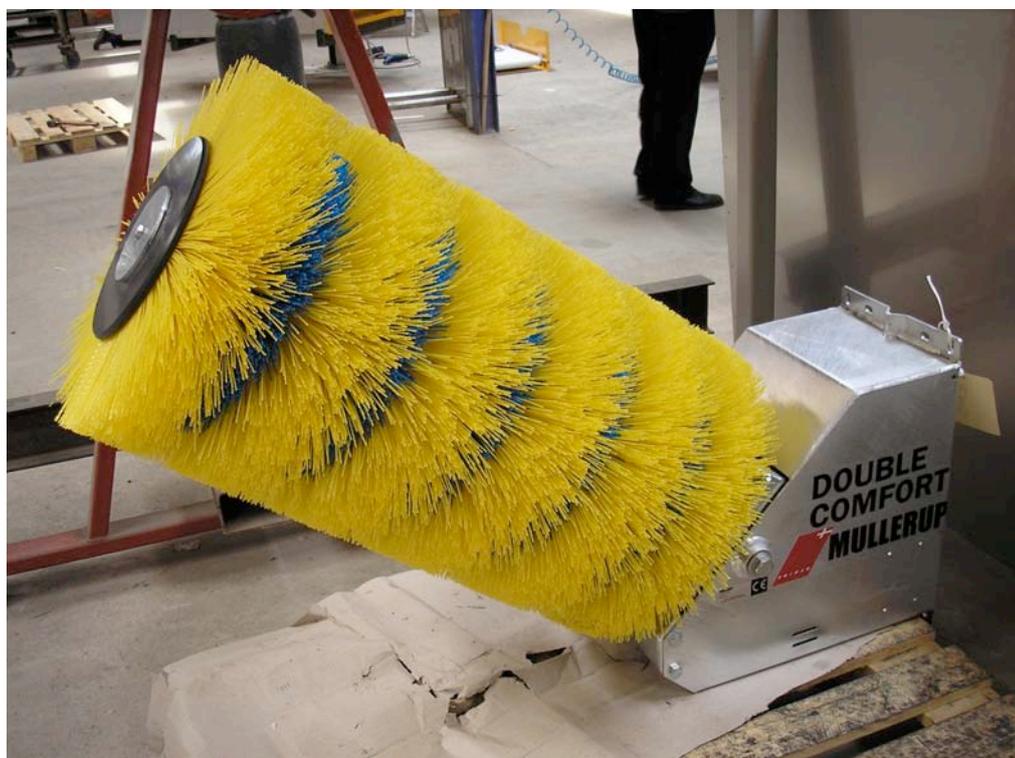


Figure 14 Cow cleaning equipment at Skiolo Mullerup.

Berne University of Applied Sciences (HSB)

The Fachhochschule in Biel is part of Innovawood; this is an organisation that was formed by organisations such as Eurologna. The University of Melbourne Centre for Advanced Wood Processing is also part of Innovawood. The school at Biel is concerned with wood engineering and architecture. The ambition and mission of the Berne University of Applied Sciences is to be a centre of excellence for teaching and applied research with both a national and international reputation, and it wants to contribute to economic growth and entrepreneurial dynamics in the region.

The facility has the following departments:

- ◆ The department of architecture, civil and wood engineering HSB.
- ◆ The department of technology and computer sciences.
- ◆ The department of economics and social work.
- ◆ The department of arts.
- ◆ The department of agronomy.
- ◆ The department of sports.

The Berne University of Applied Sciences has over 5000 students and 700 professors, some of them part-time. There are 113 students in the Department of Wood Engineering at HSB (Biel). The Wood Technology department at HSB prepares the students to take a leading position in the wood industry. This education includes the development and fabrication of wood products, planning of buildings and business management. The Swiss education system is shown in Figure 15.

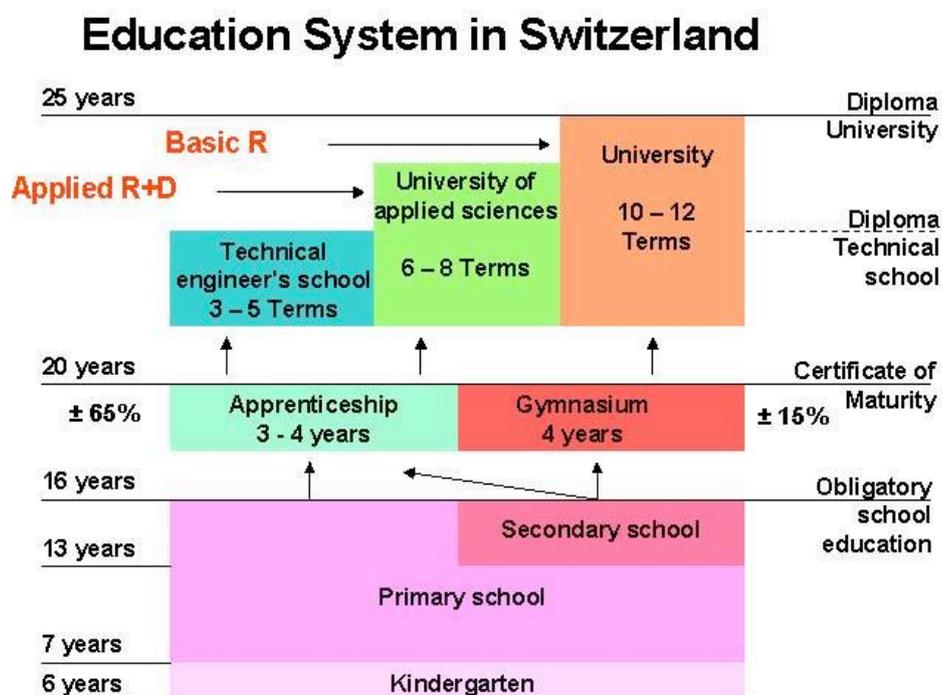


Figure 15 The Swiss education system

The University of Architecture, Civil and Wood Engineering (HSB) offers high graduated studies in the fields of Architecture, Civil and Wood Engineering. Architects, Civil and Wood Engineers carry out today a wide range of different functions. These include the construction of houses, roads and bridges, buildings to protect the landscapes as avalanches and water desasters, calculation of the bearing capacity of building elements and coordination of tools and materials. The teaching at HSB is directly linked to the national and international market.

Research conducted at the facility is partly sponsored by industry and partly by manufacturer associations and Government. Fields of study or research designed to focus on the furniture industry are automation, tool development including tool lifetime tests, and surface quality detection and rating. Specifically, these programs are standardization of IT communication in the furniture industry, Detection and rating of sanded wood surfaces, Development of self regenerating sanding tool And supported automation. In addition, a technology transfer program ensures that knowledge is passed onto the industry at minimal cost. HSB has agreements for cooperation with academic institutions in several countries worldwide, participates actively in projects of the EU Framework programs, and is active in worldwide student interchange.

The issues arising from our visit to the Berne University of Applied Sciences was the relationship between education, industry and research. A research base allows for students to be involved in the thinking and problem solving process. Research, especially when related to Industry, allows a closer interaction to the customer (industry). The University is currently involved in testing wooden roofs for weather proofing, burglar-proofing in wooden housing, robotic manufacture of windows and maintaining continual sanding of machined components through specialised sanding machinery (Figure 16).

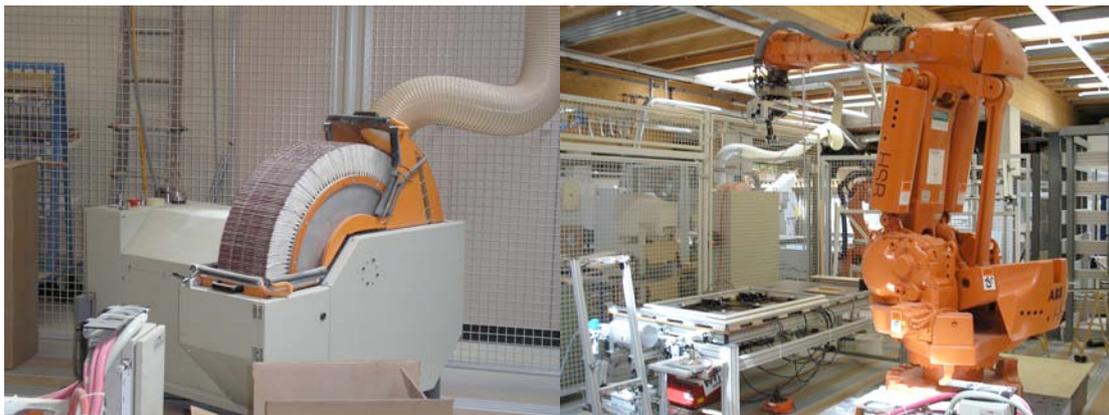


Figure 16 Continuous sanding machine and robotic window assembly

Wood Welding project, Berne University of Applied Sciences

A major research project of the Institute has been a study into wood welding. The first part of the investigation has shown that the vibration welding technology can be successfully used to connect large dimensions wood joints. Moreover, the assembly stage of the wood joints is simplified and extremely short (between 1.5 and 6 seconds) and the energy required to create the connection is efficient, being directly applied in the joint. Consequently, the welding process provides a well-tuned balance between the qualitative and economical aspects of the industrial production.

After the technological study a first evaluation of the market confirmed that the economical and technological potential of the new gluing process were definitely high. As result of this analysis, various applications were acknowledged. Due to its reliability and flexibility, the process can be easily introduced into most parts of the wood industry working on the manufacture of windows, doors, furniture and multi-layer parquet. Nevertheless, due to the characteristics of the products and the trend of the market, the multi-layers parquet industry was recognized as the main "target market". The results of an investment / cost calculation, showed that the substitution of traditional gluing processes with the new one could determine a considerable reduction of the gluing and assembling phases costs (12% of cost reduction), corresponding to a large increase of the corporate profits. According to the positive outcomes of this study, the innovation was patented and the first contacts with potential customers were taken.

Stuber

Stuber & Cie was an unusual visit in that it did not fit into our original scope. It was, however of great general interest and a change from all the CNC equipment. The company is located in Schupfen. Stuber employ fifty persons and produce laminated beams and windows. In Europe, laminated beams are used extensively for building. The company supplies by word of mouth and services the local area (approximately a 30 kilometer radius). Only four mills in Switzerland can produce beams at the lengths achieved at Stuber. Relationships with designers and architects usually lead to orders. Some cabinetry and double glazed windows are manufactured and parquetry floors are produced. No unskilled labour is used and skills are highly regarded.



Figure 17 Stuber head office and beam manufacture

The company was started in the 1890's and since 1926 has been a family business. It is now a fourth generation business. The head office and laminating press are shown in Figure 17. Species used are mostly pine (beams) with some Beech, Oak and Maple. Unlike Aicher Holzhaus in Halfing, (another German beam manufacturer) this company does not believe in "moon wood". Moon wood is timber cut at a certain phase of the moon, said to improve its drying and other properties.

This company is small by beam manufacturing standards. A typical beam manufacturer would produce in the region of 10,000 cubic metres per annum. Stuber produce 3,000 cubic metres per annum. The company uses all its own waste as heating for the factory and timber store. These get very cold during the winter months. In the summer they send their waste to a particleboard manufacturer. Beams can be as long as thirty metres in length! It was reported that Swedish wood is better for this type of manufacture than Swiss wood. Larch is also sourced from Siberia. The reasons given for the "better" quality was the growth rings being closer together, giving the beams greater strength. Bridges and buildings up to three stories high are made with laminated wooden beams. Stables, stadiums, factories and gymnasiums are also built using laminated beams from Stuber. Fifty-four metres without support is the largest that Stuber has achieved. Their own association sets standards for wooden beams. One of the professors from the Berner Fachhochschule in Biel is the association's quality controller. The beams are closely monitored for moisture content and timber defects. www.stuber-holz.ch

Fraubrunnen

Fraubrunnen produces living and bedroom furniture on a commission basis. The furniture is already sold before it is produced. The company employs seventy persons. They buy in many parts from specialist manufacturers and keep some small amounts of stock items. Approximately 2,000 parts are bought in (including hinges, glass and other fittings), and 1,000 parts are made at Fraubrunnen.



All material used in the factory is pre-cut prior to purchase; the company does not break down large sheets. The management stated that "Pre-cut and drilled pieces are cost-effective, we cannot do this any better ourselves and it would cost us more to produce. The savings in capital equipment are significant." The bought in pieces are not directly edged with melamine or other material, they have been soft formed to produce a seamless corner.



Figure 18 Fraubrunnen furniture and automated CNC technology

Fraubrunnen produce in Walnut, Maple and Beech and use a combination of veneer and melamine surfaces. They use 120,000 square metres of veneer in annually! The company has made good use of automated transfer systems and CNC equipment in a rather congested environment. Unfortunately we were unable to take photos in the factory (Figure 18) and scans from a brochure have been reproduced for this report. Fraubrunnen use mostly German technology including CNC equipment that is able to apply edges to the product on the CNC machine. The company prefers to apply the edging as

soon as the product is cut as this eliminated moisture affecting the panel. Training of operators is carried out at the machine supplier's premises and comprises one week of training for each CNC machine.

Fraubrunnen also use robotic spraying of components. About 1,000 square metres of product are sprayed a week and each part is coated three times. Sprayed product is oven-dried. Some three-dimensional parts are sprayed manually. Utilising German and Italian assembly equipment does assembly. Personal computers located throughout the factory are used to control the flow of stock and keep track of orders. Lifting equipment and overhead product transport equipment assists the workers to move product in the crowded conditions. The company uses a fair percentage of Tamil workers, prevalent in the area. These people came to Switzerland after a civil war fifteen years ago and stayed on.

The Swiss work 42 hours a week and take four weeks holiday a year. If the employee is less than twenty or more than fifty, an extra weeks holiday is provided. There are six public holidays. By comparison, in France employees work 36 hours a week.

We were able to view a large factory using much CNC equipment to produce a range of different furniture designs in panel materials. We learnt that outsourcing is common in European companies and everyone tries to produce what they do best whilst outsourcing those products that are not so well made by the company.

Fluck Werke,

Fluck Werke is located in Brienz, near Interlaken in Switzerland. The company is renowned for its children's furniture (Figure 19). The company has a German CNC machining centre but what makes the company unique is its use of robotics to feed the CNC machine. The company boasts 60,000 components in just 15 days! The uptake of robotics technology has enabled the company to operate 24 hours a day and 7 days a week. In addition, only 20 employees are required to now work in the factory.



Figure 19 Fluck Werke Kinder furniture.

This company is a leading example of the use of robotics in furniture manufacturing. Originally with a robotic spraying unit (8 years), the company has spent three months setting up the system. The current robotic (machining) installation has been operating for just two years. Of obvious concern was the possibility of errors in manufacturing, especially when the workshop was unmanned. The large development time was required to set in place safeguards against processing errors. Should the system require attention, an SMS message is automatically sent to the shop supervisor who will make the decision whether or not to rectify the problem or leave it until the staff returns.

The use of robotics will not speed up production on a piece-by-piece basis. The robot needs to position the piece against a stop, release the piece, which is then pushed against the locating stop using air driven lineal actuators. In certain cases the robot must place a piece on an angled rest, release the piece that will then (by gravity) move onto a locating stop. The robot will then pick up the piece a second time and position it on the machine table. In

addition, because of the lack of human intervention, the robot must also blow away any wood chips that may have been left by the machining cycle. The manager said, "Because the robot works all the time, you can afford to slow down and get a better cut". Our assessment of the product was that it was extremely smooth with razor sharp edges.

What the robotic installation does is to spread the machining over the maximum available time, in this case, 24/7. It is thought that the positioning time will eventually be able to be reduced, in some part by the robotics designers and in some part by the manufacturer. The company reports that the CNC machine and the robot are both easy to program. The time spent is in the little things, such as the gripper system, positioning of the workpieces (accuracy), clamps and pneumatic positioning pushers that takes time to work out.

The company produces kindergarten and library furniture. Stock is required in advance due to the cyclic nature of the orders. This happens in August when one third of the company's turnaround is delivered. The director said, "Even a small company can afford CNC and robotics due to the enormous savings that can be made." The company does not produce to a recognised standard. The market sets the standard. The director stated that it would take a novice company a year to fully set up a new robotic CNC machining installation.



Figure 20 Fluck Werke and Robotic installation

Fluck-Werke was a fascinating visit in that it showed what a small company could do with robotics. Up until this visit we had not seen a robot working in an industry CNC manufacturing situation. It was evident that while operators would no longer be required in a future CNC manufacturing installation, the ability of the technical staff would need to be improved. In addition, the ability of technicians to integrate the CNC machine and robot controls to affect a seamless dual-operation of the two pieces of equipment was paramount.

Schule fur Holzbildhauerei

The Swiss wood carving school was not an organised part of the tour, we just happened upon the facility after our visit to Fluck Werke. The school is located in Brienz and was just about to close when we arrived. Some photos are provided below.



Figure 21 Swiss carving school, Brienz

The school for wood sculpture in Brienz was founded in the year 1884, at that time under the name "Schnitzlerschule Brienz". Since 1928 it has been a kantonate technical school and the only one in Switzerland, which offers practical full time training for wood sculptors into the wood trades. Four full-time instructors and a design teacher provide the training instructions. The school offers a solid, traditional basic training. Occupation customer instruction for master training and apprentices from all of Switzerland is provided for wood sculpture.

Fachhochschule Rosenheim, Rosenheim, Germany (University of Applied Sciences).

The University of Applied Sciences offers studies for wood technology, wood building construction and extension, interior design as well as Master Degrees in wood technology. Education combines high levels of theoretical knowledge with applied practical work. The broad educational program includes industrial engineering, business management and entrepreneurship besides wood science. The product are the highly sought after Rosenheim wood engineers. This reputation is based on a national and international network of Universities and industrial partners that set demanding tasks that are resolved in degree dissertations or research projects.

The Rosenheim Institute is Germany's and arguably the World's leading Institute for technical education in the wood working industries. Similar in scope to a similar school at Bad Wildungen (Germany), Rosenheim is larger and blessed with a wider range of equipment provided mostly by machinery and products manufacturers. A sawmill and tool shop; panel manufacturing shop; machine shops; CNC workshops (Figure 22); CAD laboratories; furniture testing laboratory; veneer and wood bending facilities are attended by over 500 full-time students enrolled at the Institute.

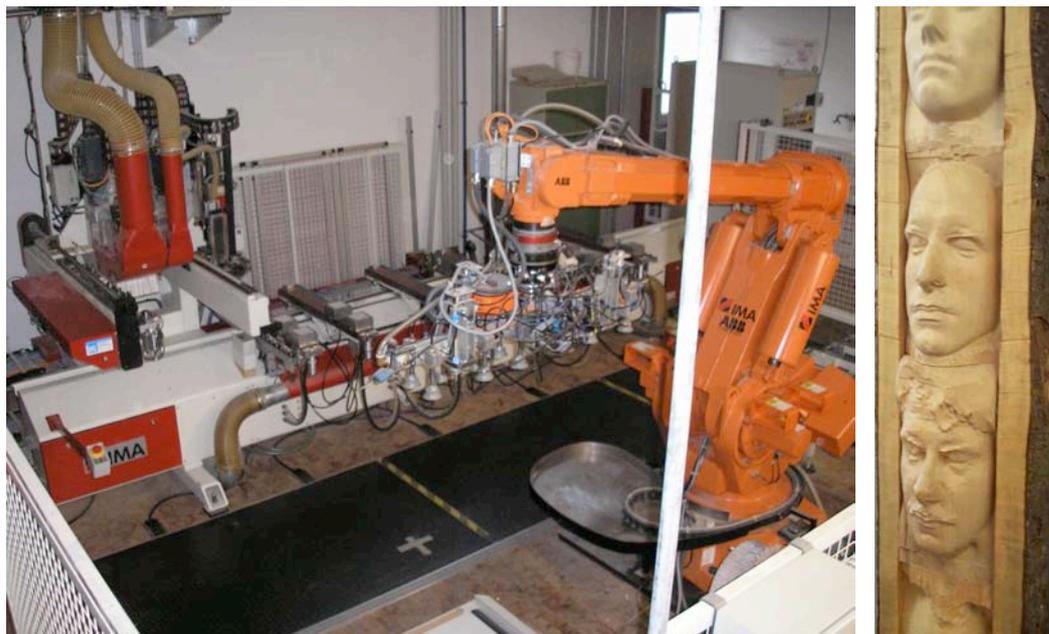


Figure 22 CNC machining centre and Robot at Rosenheim Fachhochschule

Rosenheim was founded in 1925 and has become the World's leading facility of its type. Saw milling in the local area was the reason it was first established. A saw-milling museum in Rosenheim is a worthwhile visit and recounts the history of saw milling in the area. The school contains an engineers school and a master's school. Recently the focus has been changed to cover the whole field of woodworking. The facility also includes a

plastics program. In 1972 all the Polytechnics became Universities of applied science and cover the whole range of education including dealing with logistics and administration. In 1996 the wood house building was established and now has 400 enrolled students. Franklin Wilbrink observed that the course was focused to large manufacturers and changed to cater for small to medium business. Industry was not very prepared to spend money on training.

The school has an industry group to consult on the courses offered. No fees are charged as the school is government funded. There are plans to introduce fees in the future, as Germany is one of the last countries in Europe not to charge its students. Other countries have more persons in need of education but this is not free of cost. There is some pressure to earn private funds. There is also some funding for research and development but if the school takes in too much, there will be some taxation issues. A model would be to set up a private company to handle this fee for service activities. The workshops are not used for production, as this is a sensitive point with the local industry. This is a similar situation to Australia.

The programs at Rosenheim are as flexible as possible. Every effort is made to cater for individual needs. The final stage of a masters program is a planned layout of an entire company; an example was a chair manufacturer to complete 5,000 chairs a day. Production and all logistics is planned in a theoretical situation.

Professor Scholz (Dean of school) stated "Engineers are needed in the wood working industries to optimise the processes". He said, "Half of the CNC applications in Germany are ineffective due to lack of knowledge of the equipment or the processes" and you "cannot produce low value products, even with CNC technologies (to compete with low-cost imports)". He said that most wood working shops could use the potential of CNC machinery and should look at moving from a low-value product to a high-value product base. Companies should realise they cannot compete on a cost basis (Hungary's labour rates are presently 30% that of Germany). The tendency in Germany is for larger, smarter companies to buy smaller, less-innovative companies.

Rosenheim's CNC equipment includes CAD laboratories, three and four-axis CNC machines, automatic furniture assembly machines and robotic handling equipment. CNC training at Rosenheim is well advanced as can be seen in the photo of student faces, scanned and carved using CNC technologies. The training in CNC technologies includes measuring cutting forces and learning about the interface between software and CNC equipment (What's behind the CNC program). Groups of six or seven students are most common for workshop situations, larger groups are common for demonstrations and theory classes. An interesting observation on one of the CAD room walls was a quote attributed to Albert Einstein that read, "Imagination is more important than knowledge".

Other interesting comments were:

- ◆ Does innovation have to be an elusive quest?
- ◆ To invent is to innovate.
- ◆ Give me brain, vision, tools.
- ◆ I have theory. I need action.
- ◆ I cannot attack if I have the problems of the present.
- ◆ Strive for excellence, not just competence

German production is generally small job lots. There are some large manufacturers such as Werndl Steelcase producing a million dollars worth of stock a week, but in the main, companies are similar to Australian in size and scope. The normal job lot is from 2 to 30 pieces. This means that flexible CNC machinery is required.

Unifor, Turate (Como), Italy.

Unifor have an annual turnover of 270 million Euros. The company is extensive and uses a large amount of CNC machinery and automated processes. The company specialises in designer furniture using metal and veneer boards as the primary material. Some veneer is actually laid on aluminium and other metallic substrates! The company has outlets in Australia and regards this country as a “big” market. Another major market is in Dubai. The company has recently completed the Bloomberg offices in New York for 6,000 persons! Their local market share is rather small and 70% of product is manufactured for export. One comment that we heard was that “In Italy, if you want to build, you have to knock something down that has been there for 1,000 years!” Unifor has a partnership with Vitra chairs worldwide.

Unifor is a family company manufacturing office, kitchen and wall system furniture. Unifor supplies equipment for its subcontractors and invests in their future. The subcontractors are allowed to use this equipment for other uses even though Unifor owns it. The company is moving away from solid timber in almost all areas of its enterprise. Unifor is also moving away from formaldehyde-based adhesives to zero emission adhesives. As this affects the strength of the product, the company is moving more to steel in the construction of product. The company specialises in forming for curved construction (Figure 23).



Figure 23 Unifor product and form-work.

At Unifor, the supply of raw material appeared to dictate design. For example, the manufacture of metal furniture covered with veneer or vinyl or other similar materials formed the basis of some design. The material issue was followed by the need for the design to accommodate a given number of computer workstations. Unifor do not design and then market; they go into the market, find out what the job is and then design for purpose. The construction is very neat and detail is superb. Much attention is given to the detail of the finish. Attention to detail is what sells the product. At Unifor, a product is never taken out of production. It may not be in the current catalog but can always be built for a new customer. Some of their designs are twenty years old and still being

manufactured. Often, the designers are freelance; one such person is Michaela Diluci. The relationship with designers is very personal and often, twelve months are required to realize a new design. Often, up to a hundred mock-ups are required before a product is actually manufactured.

The strength of the product is an important selling point at Unifor. A round table with a metal base was so solid that we could sit on the edge of the top without it tipping over. The owner of the company (Piero Moltoni) is also the head engineer and is very hands-on. He is not concerned with traditional methods of construction; it's what works that counts. Mostly, architects drive designs and the trends are taken from here. From a marketing point of view, the product between companies is very similar so lead (delivery) time is an important factor in getting the sale. It is seen as critical to be on time and on budget. "You cannot afford to make enemies," says Craig Raison, our host. In addition to this, it was reported that no one in the company cuts corners and everything is done to the best of their abilities. Some excess stock is kept to allow for sudden new orders; this is due to the complex construction used in some of the curved constructions.

Outcomes of the fellowship

European countries have a high level of appreciation for training and knowledge. Unlike Australia, it is almost impossible to get a job in a trade area without a qualification. A high level of co-operation exists between their TAFE equivalent and Industry. In Denmark for instance, Industry highly values qualifications and foster high levels of skills. Students are provided with substantial income support while training. A high staff to student ratio also assists with good training regimes. Their pre-apprenticeship programs differ to Australia in that the students do a range of subjects that enable them to choose different career options at the completion of the course. There exists the means for students to leave and re-enter the education system. Young people are well catered for educationally. The country supports this with higher taxes, but the public sees where this is being well used and accepts this.

This situation is almost the opposite in Australia. In this country we value education but are not prepared to pay for it. Industry no longer places apprentices in the numbers it did ten or more years ago. On the other hand, manufacturers will tell you that they are unable to attract young school leavers into the trades with the same ease of the last decade. Young persons are not attracted into any of the “factory” trades and government views that “the longer a young person stays in school, the better chance they have of finding employment” are seriously affecting the traditional trade “pool”.

The fellows are now in a stronger position to provide more meaningful training on CNC manufacturing. The experience has been invaluable in providing a snapshot of our immediate future. Many countries are facing the same issues as us. In Denmark for example, the country has a population smaller than ours, yet produces a third of the World’s mobile phones. In the furniture industry, manufacturers sell leading designs around the World. The perceived “threat” from China and other low labour cost countries is being met with quality and design.

The participants are now in a position to implement the mentor study communication pathway shown in Figure 1. This has begun with four meetings a year in various TAFE Institutes around Victoria. Visits from suppliers have been organised, and advice and information is being disseminated via our website at www.camtag.org.au where the minutes of recent meetings can be viewed.

Recommendations

Government

- ◆ Foster the value of the trades and encourage young people to enter the trades' areas, especially the furniture industry. The industry now has a chronic shortage of skilled persons capable of using sophisticated equipment in an effective manner.
- ◆ Provide financial or tax incentives to companies in endangered trade areas (furnishing).
- ◆ Provide funding to relevant RTO's to upgrade equipment and software. The Victorian government has been generous in providing technology grants to TAFE but this is not targeted and the RTO's have set their own priorities; this has not often included the furniture industry.
- ◆ Continue to support ISS study programs. Continue to support staff development activities in RTO's.
- ◆ Provide support and funding for programs to allow persons to re-enter the industry. Many young persons leave the trades and never return; some incentives could be provided to assist them to return.
- ◆ Support lean manufacturing initiatives; this could include lean manufacturing training or incorporating lean manufacturing into existing training packages. It was evident (in Europe) that lean manufacturing is a way of becoming more competitive on both domestic and international markets.
- ◆ Consider funding models to allow smaller groups (six or eight) for CNC manufacturing training where (in almost every case) only one machine is available (in the TAFE Institute) for training.

Industry

- ◆ Provide release for training in CNC, and design and manufacturing for existing workers. Many existing workers have no formal training.
- ◆ Provide apprentice places for young school leavers and actively promote the apprenticeship system in local secondary schools. Promote the furnishing trade as one in which technology plays a part.
- ◆ With the introduction of CNC machinery and equipment and the ability to hire casuals and process workers to operate these machines, most companies should be able to look at employing a CNC "engineer" to assist in the setting, programming and running of CNC equipment.
- ◆ Work with retailers to promote Australian product, Australian design and Australian-made quality.
- ◆ Work with designers to produce unique Australian designs. Find out what Australian design is. Do we have a design identity?
- ◆ Find a means of attracting Australian buyers to the furnishing product.
- ◆ Retailers must provide training for sales staff to identify Australian-made quality, timbers and other issues affecting the consumer choice. Very few furniture sales persons have any formal training in the product.

- ◆ Produce a quality product; do not compete on price.
- ◆ Use technology and software to streamline the manufacturing process.
- ◆ Use high-performance tooling to raise machine feed speeds and improve surface quality, reducing the need for sanding and re-work. Training in cutting processes would raise awareness of quality issues caused by low-performance tooling and poor housekeeping.
- ◆ A greater understanding of mechanical fixing, jig construction and part holding would benefit Australian companies.
- ◆ Outsource work not in the immediate company's area of expertise; this keeps costs down and enables the company to concentrate on what it does best.
- ◆ Introduce lean manufacturing principles. This includes focusing on small batch sizes down to a batch size of one.

Professional Associations

- ◆ Work with industry and RTO's to find a way of attracting more young people into the trades.
- ◆ Work with industry and RTO's to set up training programs in areas such as furniture design, furniture design for CNC manufacture, and CNC manufacturing.
- ◆ Provide information for the public domain on Australian timbers, design and quality.

Suppliers

- ◆ Support RTO's and teacher groups with up to date literature, training materials etc. including videos and other relevant materials.
- ◆ Continue to support RTO's with discounts on new machinery and software.

Training providers

- ◆ Continue to provide high-quality training.
- ◆ Promote industrial release programs and support study tour initiatives.
- ◆ Allocate funding to technology areas for equipment, software and staff training.
- ◆ Provide training and information seminars on new technologies and existing skills shortage areas.
- ◆ Consider the provision of research and development activities for industry.
- ◆ Allow further (industry, public) use of TAFE equipment, software and teaching staff on a cost-recovery basis where this use does not conflict with the TAFE charter.
- ◆ Consider funding models to allow smaller groups (six or eight) for CNC manufacturing training where only one machine is available.

International Specialised Skills

- ◆ Continue to provide support for the furniture and design sectors.
- ◆ Assist and support the establishment of a specialist CNC manufacturing and design centre at Holmesglen Institute.
- ◆ Consider allocating further study funds to CNC teaching staff to improve knowledge of CNC manufacturing on an International level.
- ◆ Support the production of texts on CNC manufacturing and furniture design and manufacturing. There are no modern recognised texts covering these specific learning outcomes.

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