

Interior
Design
Guide

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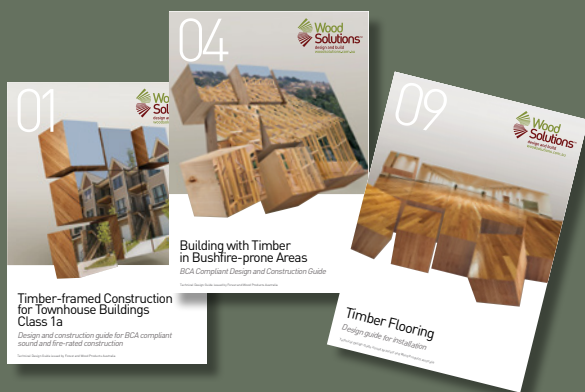


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Reimagining Wood-based Office Fitout Systems

Design Criteria and Design Concepts



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Contents

1	Introduction	4
2	Research-based Design	5
1.	Introduction	3
2.	Research-based Design	4
3	Other Key Impacts on Design	6
3.1	Client and Worker Perceptions	6
3.2	Office Futures	6
3.3	Supply Chain and Delivery	6
4	Design Criteria	8
4.1	Materiality and configurability	8
4.2	Deconstructability	8
4.3	Critical handling	8
4.4	Changes in fitout style and scope	8
4.5	Digitally driven DFMA	8
5	Timber Design Systems – Key Product Areas	9
5.1	Wood Partition Walls – A Modular Hollow Core System	9
5.1.1	The concept	9
5.1.2	Having an impact at the right place in the supply chain	10
5.1.3	Design details	10
5.1.4	Channels, fixing and support	11
5.1.5	Services	11
5.1.6	The wood-based hollow core design in practice	12
5.2	Workstations Using a Reconfigurable Kit of Parts	12
5.2.1	The concept	13
5.2.2	3D printable joiners and dowels	14
5.2.3	Details on parametric design	14
5.3	Furniture Using Open Source Designs	15
5.3.1	The concept	15
5.3.2	Manufacturing open source furniture in practice	15
5.3.3	Open source products with parametric design applied	16
5.4	Ceiling Tiles and Existing Products	16
6	A Life Cycle Assessment Comparing Wood-Based and Traditional Fitout	17
7	Conclusions	18
8	References	19

1 Introduction

Timber has a unique place in the construction industry. At one end of the scale, it is a fundamental structural component (it has strength, can be organised into structural framing and allows diverse shapes); at the other end, fitout owners often specify timber as an expression of quality that projects the company's values to their clients and staff.

While timber is common in residential construction, its application has declined in commercial office fitouts. For example, its use in office partitioning has been almost completely replaced by steel-framed plasterboard. At best, it is used as a preferred and aesthetically appealing outer skin. Where it is used, many of the workstations and other products are manufactured overseas.

However, opportunities to introduce timber are emerging as trends toward open plan offices move away from constructed solutions and toward furniture-based design. The increasing emphasis on sustainability assessment, new ways of working, office workers who value richer engagement with their workspaces, and a broader awareness of the recurring embodied energy/carbon in each office re-fit, all point to new possibilities in office fitout.

This guide seeks to expand the view of timber as an 'aesthetic skin' to include new forms of engagement. It deals specifically with the development of design concepts for new wood-based office fitout systems revolving around environmental sustainability outcomes. The emphasis is on reducing the recurring physical waste and embodied carbon/energy brought about by the 'fitout-stripout-repeat' cycle that commonly arises from lease churn over the life of office buildings. This is primarily achieved by designing with a view to increased reuse and recycling, and by taking advantage of the inherent benefits of timber as a sustainable construction material. Designs particularly focus on partitions, workstations, furniture and suspended ceiling tiles.

2 Research-based Design

A parallel research report to this guide, ‘Increasing Wood-based Office Fitout for Sustainable Life Cycle Benefits’ (download at www.fwpa.com.au), provides evidence-based research findings that inform the design concepts developed in this document. For instance, that report:

- quantifies and qualifies office lease and fitout churn cycles
- quantifies and qualifies physical waste from stripout processes including problems for reusing/recycling waste
- compares embodied energy/carbon for wood versus traditional fitout, using a Life Cycle Assessment approach.

While these findings have markedly influenced design, attention is also given to other features central to successful fitout design, including architectural, supply chain, tenant, building owner, cost and fitout/stripout contractor needs.

2.1 Research into the ‘Fitout-Stripout-Repeat’ Sustainability Loop

The design approach in this guide is based on research-based evidence. A continuous cycle commonly evident from the research is defined in Figure 1. It involves a three-step process that, from a sustainability perspective, begins when an outgoing tenant reaches the end of their lease, triggering the ubiquitous ‘Make Good’ clause. Stage 1, covers removal of their fitout; Stage 2 involves reinstatement of what was originally in place; Stage 3 covers the new fitout installed by the incoming tenant. Ultimately, this results in a repetitive cycle as tenants come and go from the building. Design decisions lack visibility at the ‘Make Good’ and ‘Stripout’ stages of the process, which creates disconnections that prevent closure of the sustainability loop and cause poor reuse and recycling outcomes.

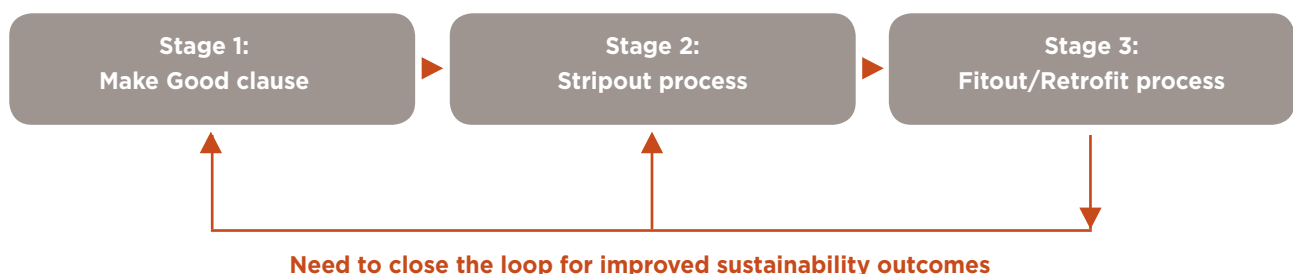


Figure 1: The ‘fitout-stripout-repeat’ cycle and the sustainability loop problem.

It is worth looking into the factors that influence each stage in the Figure 1 model more closely. For instance, the ‘Make Good’ clause potentially creates triple waste because it will likely induce:

- stripout by the outgoing tenant
- temporary reinstatement of the original fitout
- a new fitout by the incoming tenant.

The ‘Stripout’ stage (Stage 1) typically involves the building owner’s capital works team and outgoing tenant. The actual process is characterised by the following constraints:

- Speed is paramount to reduce lost rent or usage of the building.
- Work is often done after hours at extra cost and extra process to meet inter-tenancy rules and to have uninterrupted access to the goods lift and loading bay.
- The goods lift and truck cartage cycles dominate other processes.

- Waste is separated into streams if easy and worthwhile in terms of reuse/recycling costs; if not at least cost neutral, it will go to landfill.
- Volumetric items (e.g. workstations) are generally not economically viable to reuse/recycle.
- Creating sufficient economies of scale to make reuse/recycling worthwhile is usually linked to the critical mass of a homogenous waste stream.
- Reuse/recycling is more viable if depots are close by, as this reduces cartage costs and improves the ability for truck shuttle times to coordinate with site processes.

The 'Fitout' stage (Stage 3) typically involves the building owner's leasing team and the incoming tenant. Issues include:

- Designing for aesthetics and corporate needs dominate.
- Sustainability may have an impact on design, depending on the tenant's targeted environmental expectations, the base building's sustainability rating and the building owner's environmental expectations.

The decisions made up front at the fitout design stage may not take into account what will happen at the stripout stage, in terms of reuse and recycling. This distances levels of accountability for the chosen fitout materials as the cycle progresses.

The current specification of wood primarily revolves around a conversation between client and designer concerning aesthetics. As an example, relatively little detail is provided about the underlying construction of partition walls because the main issue is the appearance of the outer skin. ***The first sustainability loop disconnection is made because*** the client is blind to, and often has no explicit opinion on, many construction materials, and has no vision of the likely end of life implications arising from their choices.

The designer then turns their attention to what it takes for the partition wall to be documented for construction. They may typically take a conservative approach and tap into conventional fitout construction methods in order to seek a competitive price (e.g. a steel-framed structure with plasterboard lining and glass partitions). Such assemblies can be difficult to deconstruct and so little consideration is made for the end-of-life treatment of the partition wall. ***The second disconnection in the sustainability loop is made.***

At the end of the partition wall's life, the stripout contractor will assess its removal based primarily on past knowledge of what they expect to exist beneath the outer plasterboard layer. The waste will likely be a split of separated materials that can be recycled and mixed materials that can't be easily separated or have limited reuse and recycling value. Unfortunately, the mixed materials usually go to landfill. ***The third disconnection in the sustainability loop is made.***

At each stage, some accountability for fitout materials at the end of their use is relinquished. Improving visibility and accountability along the stages in the loop would set the design direction for the sustainable use of wood in fitouts.

2.2 Quantifying and Qualifying Fitout Churn and Waste

- Fitout has a short life span that should be designed for reuse and recycling. Research indicates that fitout churn falls within a range of 5.0–8.9 years; small tenants tend to be in the lower range and large tenants in the upper range.
- Where no significant efforts have been made for reuse and recycling onsite, the research indicates that about 64% of the material goes to landfill. Where efforts have been made to improve waste management, the tables can be turned so that 61% of waste can be diverted from landfill. For details, refer to report *Increasing Wood-based Office Fitout for Sustainable Life Cycle Benefits*, downloadable at www.FWPA.com.au
- Saving materials from landfill involves a fundamental problem of mixed material. The difficulty in separating components leads to demolishers sending such materials to landfill. For details, refer to the report *Increasing Wood-based Office Fitout for Sustainable Life Cycle Benefits*, downloadable at www.FWPA.com.au.
- Recycling and reuse only occurs where there is sufficient critical mass, homogeneous materials are easy to separate, and/or there is easy access to reuse/recycling depots and/or resale markets. Wood often has insufficient critical mass and is hard to separate by virtue of being part of composite materials and assemblies – it often becomes part of mixed waste going to landfill.

3 Other Key Impacts on Design

3.1 Client and Worker Perceptions

Wilmot et al (2014) indicate that new materials are often preferred under the broad understanding that, “New materials are so cheap that the additional handling and transport required, makes reused or reprocessed materials unable to compete”. ‘New’ means you can search, compare and order from a catalogue with assured knowledge of material choice, quality, size, availability and warranty. There is much less room to manoeuvre when considering reused or recycled materials.

New fitout enables a company to have conversations with staff around the quality of their future work environment, which can be a significant component in the change management process. Companies need to have a well-articulated position on resource recovery and attract like-minded staff to value fitout reuse and recycling. To support this, there is a need to focus on retaining value when designing for reuse and recycling.

3.2 Office Futures

“The emphasis on making and prototyping, along with the rise of a project-centred workforce, will change the nature of workspace and how it’s provided. Look for the emergence of just-in-time settings designed to support the activities of fast-moving, constantly changing teams.” Gensler Workplace Forecast (2016)

Gensler says we have to be aware of “the emergence of just in time settings”. Doing business in office settings in the future is less likely to look very much like the offices of the past, or even the present. The physical space of buildings may not change, but the amount of space, type of space, location and base building technology is likely to keep changing. This change is, in part, driven by the increasing capacity of mobile connectivity and the natural expectation that work/productivity is not related to inhabiting 12 m² of personal commercial real estate for 7 hours a day. Technology increasingly blurs the physical footprint of the workplace, and this landscape has no defined boundaries. As Gensler indicates, it is likely that the design of the new workplace fitout will respond to this fluidity.

The new office is likely to mean less focus on permanent construction and more potential for a furniture-driven approach (including the use of furniture design principles to create flexible partitioning systems). This is an important trend that potentially benefits wood-based fitout because of the suitability of wood panel products to scalable, cost effective and automated furniture production processes. For instance, BIM-oriented 3D design and computerised wood cutting/processing equipment can accomplish much in terms of providing cost-effective, customisable and automated small batch production processes that are less reliant on overseas manufacture.

3.3 Supply Chain and Delivery

The proposed design concepts need to be compatible with the idiosyncrasies and complexities of the supply chain involved. Workstations that dominate project budgets often come from overseas with long lead times that effectively reduce the fitout contractor’s level of project control. Re-empowering fitout contractors would be useful in having greater control and efficiency; improved cost effectiveness; better customisation potential; and greater ability to assemble in Australia.

Greater integration of the supply chain is needed, including actively adopting concepts such as ‘design for manufacture and assembly’. In fact, given the obvious need for reuse and recycling in fitout, this term can be extended to ‘design for manufacture, assembly and **disassembly**’ (DFMAD). Such an approach aims to offer a way to harness digital technology (across clients, designers, manufacturers, fitout and stripout contractors) by making use of technologies such as computer numeric cutting files (CNC), 3D printing files and parametric designs that can change to suit scalability needs. The intention is also to create greater visibility to reduce the disconnects in the sustainability loop.

There is potential to both compress and simplify the supply chain under a wood-based approach, including shorter lead times, reduced purchase of separate parts, and an improved ability to have a smooth transition from design to fabrication to site construction.

Such an approach could optimise use of basic carpentry skills to cover a large part of the fitout work, creating simplified workflows, and work and project management requirements.

4 Design Criteria

Fitout design concepts need to come up with systems that can offer multi-generational value, without feeling 'second hand'. Timber can be an underpinning material in fitouts that have refined potential for reuse and recycling markets. In terms of strategic design, criteria include:

4.1 Materiality and configurability

- Incorporate more timber in fitouts to create sufficient critical mass for reuse and recycling practices to develop.
- Design for reuse and recycling at the beginning of the fitout process.
- Use a relatively homogenous palette of materials.
- Use a minimal kit of parts.
- Develop multi-purpose scalable components.
- Design for re-configurability to extend reuse options.
- Develop assemblies that allow incorporation of services (e.g. cabling).

4.2 Deconstructability

- Ensure fast knockdown from volumetric to flat and stackable.
- Avoid special dismantling tools.
- Ensure compact stacking to optimise goods lift usage and efficient truck cartage.
- Ensure wood panels and workstation tops are easily separated from the support frames beneath.
- Create quiet deconstruction methods to allow more work during normal office hours.

4.3 Critical handling

- Ensure fast stripout that maintains flow from breakdown-to-lift, lift-to-truck, and truck-to-depot.

4.4 Changes in fitout style and scope

- Take advantage of open plan offices that allow greater utilisation of a furniture-based design approach.
- Broaden timber-based tender packages to compress and simplify the supply chain.

4.5 Digitally driven DFMA

- Create scalability by using parametric design, i.e. where a 3D model of an assembly (such as a shelving unit) can be changed in size and the rest of the componentry and proportions change accordingly.
- Use 3D printing for components that join timber pieces together and can be automatically re-sized using parametric modelling.
- Use computer numeric cutting (CNC) machines to automatically cut pieces for an assembly, from a digital file.

5 Timber Design Systems – Key Product Areas

The focus in the design process needs to be around key fitout items that constitute the major proportion of fitout works/costs:¹

- partitions – lightweight, reconfigurable and deconstructible
- workstations – scalable, reconfigurable and customisable in Australia
- furniture – including scalable shelf and storage units, pedestals and miscellaneous tables
- ceiling tiles for suspended ceilings – including utilisation of established product lines.



Figure 2: Key product areas.

The partition and workstation concepts use a (partly) common kit of parts that can be quickly disassembled and reassembled. They do not need specialist manufacturer teams to do this, thus ensuring simplicity, flexibility, economies of scale, construction efficiency and importantly, critical mass to encourage reuse and recycling.

The furniture concepts take advantage of open source designs that have been modified by the authors to allow scalable, parametric design capable of a file-to-factory-to-site approach. These designs utilise 3D modelling that can be sent to a CNC cutting machine and once this is done, sent as flat pack to site for easy and fast assembly. Such units can be made to order at short notice and do not need specialist manufacturers, designers or lengthy procurement times (or lengthy delivery distances). They are relatively homogenous and don't depend on specialist parts or proprietary manufacturing systems.

For completeness, existing products have been co-opted into the design field for ceiling tiles (these products are only suggestions that can be coupled with the above). These products already exist in established markets and include:

- ceiling tiles capable of both front-of-house and back-of-house applications
- existing plywood acoustic ceiling tile products that can be routed with noise capture patterns and sound absorbent backing according to project specific needs; high-quality powder coated finishes are possible.

¹ Less potential appears to exist in other parts of fitout such as floor coverings where carpet is the main option – it is cheap, fast to lay and easy to remove (especially tiles with pressure sensitive glue). Some carpet tile manufacturers also have advanced recycling schemes. The same applies to seating as there is an established need for these to be supplied separately and to meet specific comfort and ergonomic criteria.

These conceptual ideas have been developed to a level of functional feasibility that could be further developed by industry as new products. The models and physical prototyping that have been undertaken indicate proof of concept and function rather than trying to exhibit a finished working product. The general level of design development provides for industry wide uptake while still allowing individual proprietary input that may enhance competitive advantage.

5.1 Wood Partition Walls - A Modular Hollow Core System

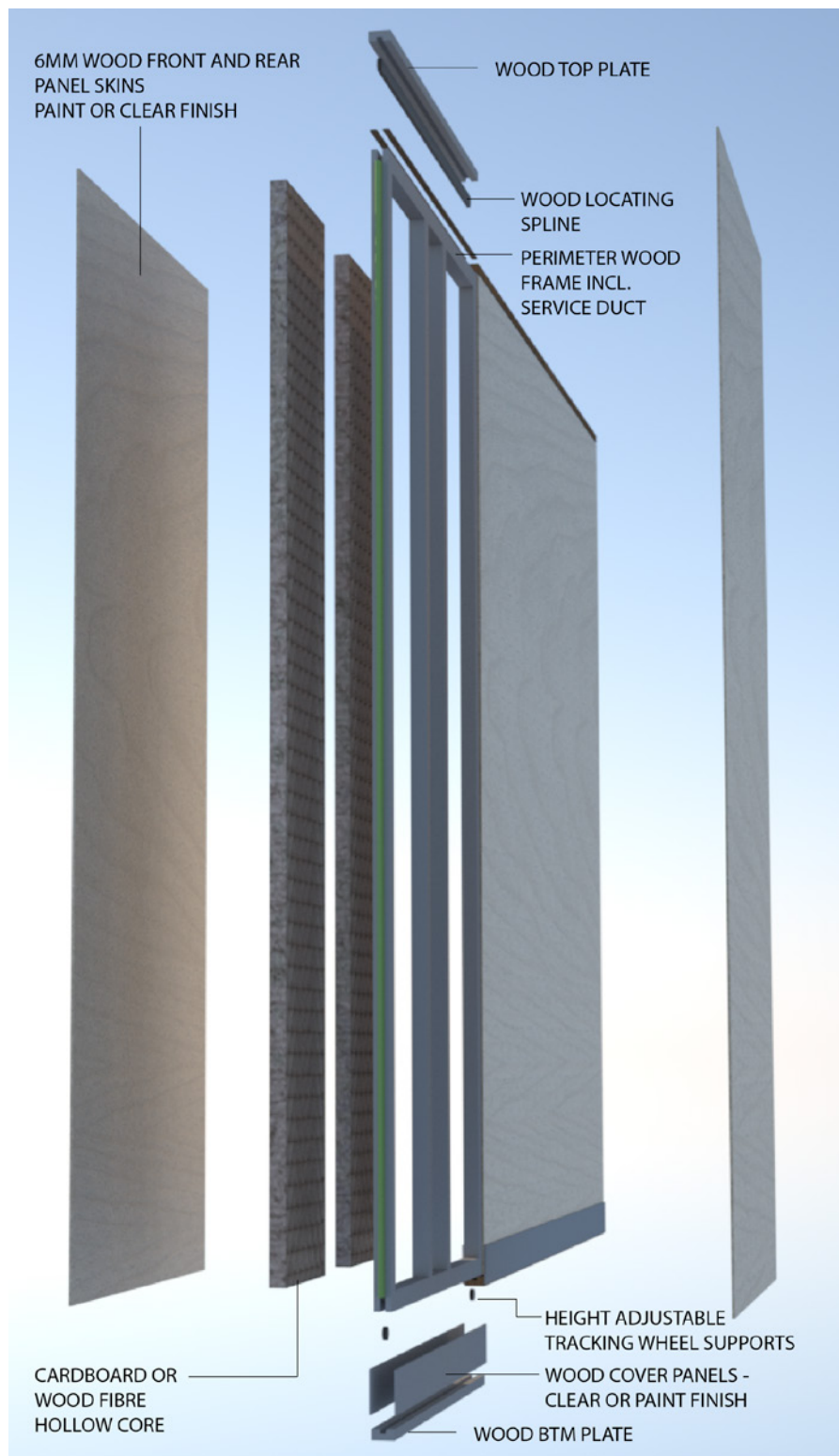


Figure 3: Timber partition panel concept, UTS 2016.

5.1.1 The concept

The concept for a new wood-based partitioning system is a response to the past reliance on multiple materials and trades to construct steel stud and plasterboard partition systems. The modular panel concept responds directly to the design criteria presented in Section 4 (as presented in Figure 4). For instance, it:

- responds to evolving work situations over the life of a lease
- is simple to install/deconstruct and is able to be reused without depending on multiple trades
- utilises a homogenous timber-oriented material palette to improve reuse and recycling consisting of timber skins, timber frame, minimal (starch-based) glue and expanded cardboard filling
- aims to leverage existing manufacturing businesses – primarily the door manufacturing industry discussed further below
- compresses and simplifies the supply chain both in material supply, work packaging and in transition from design to manufacture to assembly and finally, disassembly.

The approach does not require permanent structures or walls to be demolished at each churn in fitout. It does not rely on a lengthy construction process and its materials and construction technology are flexible.

While the outer skins for such panels can be pitched at competing with common plasterboard finishes using the likes of hardboard, this system also lends itself to higher-grade finishes, such as plywoods with high end decorative veneers. The hollow core, modular, timber panel is designed so that it can be used interchangeably as wall partitions, workstation partitions or work station benchtops (see section 5.2).

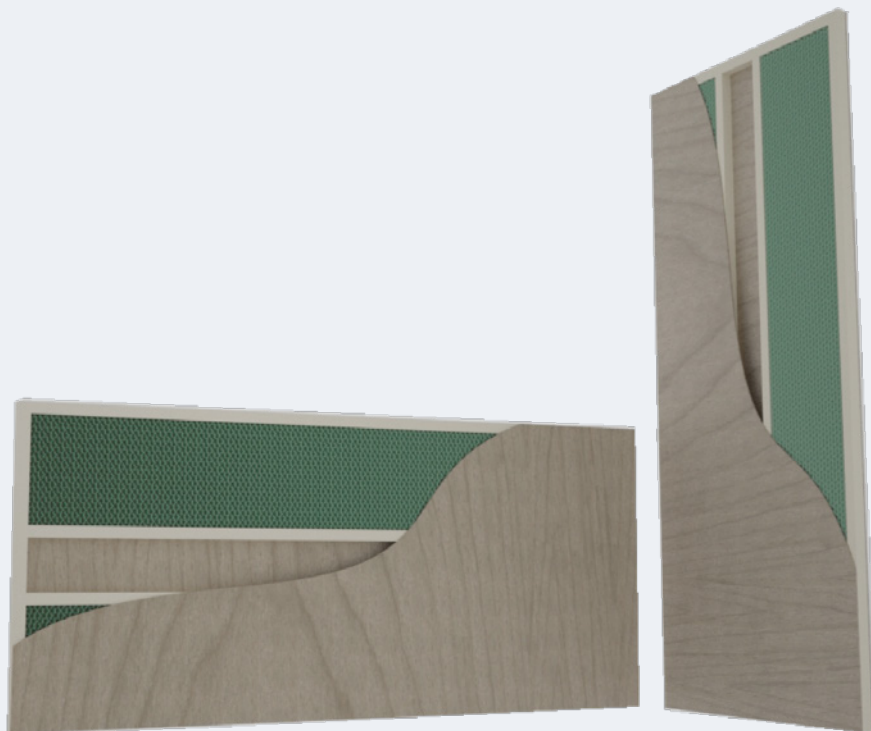


Figure 4: Final concept iteration, UTS 2016.

5.1.2 Having an impact at the right place in the supply chain

This approach adapts existing door manufacturing techniques that aim to provide a cost-effective and well-developed base.² For instance, door manufacture goes beyond basic raw materials by providing a more value-added and prefabricated product centred around wood. Even so, its location in the fitout delivery process means that it still allows design flexibility and is well known in day-to-day specification and purchasing by designers and fitout contractors alike.

² Hume Doors and Timber (www.humedoors.com.au/), one of the largest door manufacturers in Australia, assisted with prototyping, cost information and feedback about manufacturability criteria of UTS's original design concepts.

Door manufacture typically includes: economies of scale; cost effective and efficient manufacturing processes; well-developed compliance and quality assurance systems; certification under common sustainability assessment schemes including FSC and PEFC; ability to upgrade to meet fire and sound performance as part of normal manufacturing processes; Australia-wide distribution networks; recognition in existing supply chains in the fitout industry; supply of ancillary fitout materials.

Door manufacture also offers broad scope in terms of client-driven customisability, including customisable unit sizes as well as panel veneers, skins, cores and finishes. The existing carpentry workforce has deep tacit knowledge, thus offering a readily available workforce for installation needs



Figure 5: Manufacture and warehousing, Hume Doors, Lansvale NSW.



Figure 6: Distribution, Hume Doors, Lansvale, 2016.

5.1.3 Design Details

The primary unit size is targeted at a 2,700 x 1,200 x 45 mm panel so that panels can be dimensionally coordinated with typical ceiling grid modules. Height can be scaled to a maximum 3,000 mm, which should deal with most ceiling heights. Width can be scaled to a variety of typical door widths of 820 mm, 870 mm, 920 mm, and to less standard widths of 410, 420, 460, 520, 620, 720 and 770 mm.

The thickness profile is important as it includes thicker-than-normal door skins (2 x 6 mm thick wood panel skins) and deeper-than-normal timber edge rails at 33 mm wide x 50 mm deep. There is also 33 mm wide x 50 mm deep framing pieces defining the central services duct. This provides a strong and impact-resistant unit that will not sag under the intended non-structural office use loads. Even so, this thickness is considerably less than equivalent steel stud and plasterboard partition walls, thus yielding extra usable floor space.

Joining of panels is facilitated by a routed groove along all edges of the panels. This creates flexibility in terms of joining options:

- The grooves of opposing panels receive a spline (inserted into each panel). This can be widened to show off the natural features of a decorative timber spline or reduced to either hide the joint or create a shadow line using less expensive timber.
- At the bottom of panels, the groove is used to accept adjustable rollers commonly used by door manufacturers in sliding door assemblies. These allow the panels to be adjusted for plumb and aim to assist work flow by having one worker loading panels onto the track while the other pulls them into place and fixes them (at the bottom, behind the skirting piece, see Figure 9). On top, simple locating guides (short sections of spline material) fit into the top groove.
- At stop ends where edges are exposed or where a starter piece is required to build out from an existing wall, a milled timber 'T' section can be inserted into the groove. Again, this could be made from decorative or less-expensive timber according to aesthetic needs.

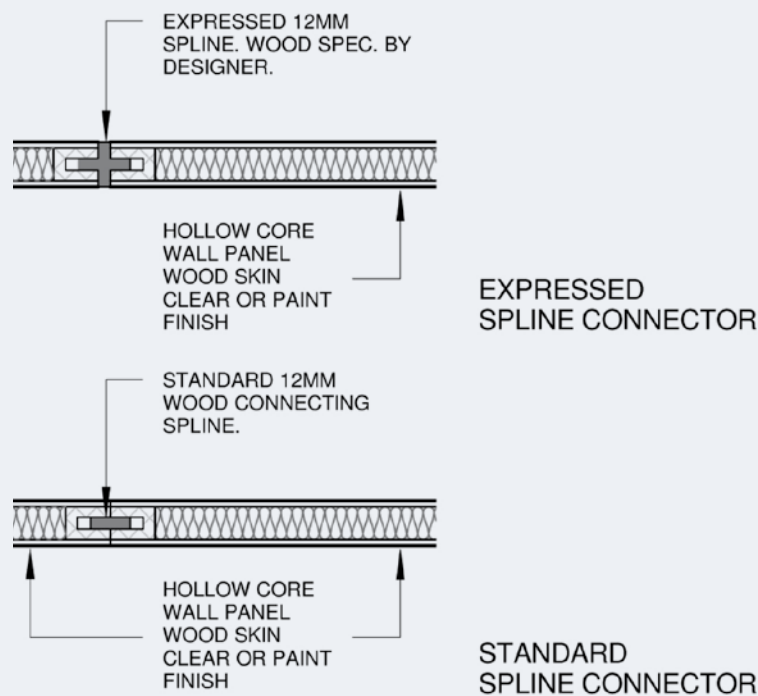


Figure 7: Spline used to join panels.

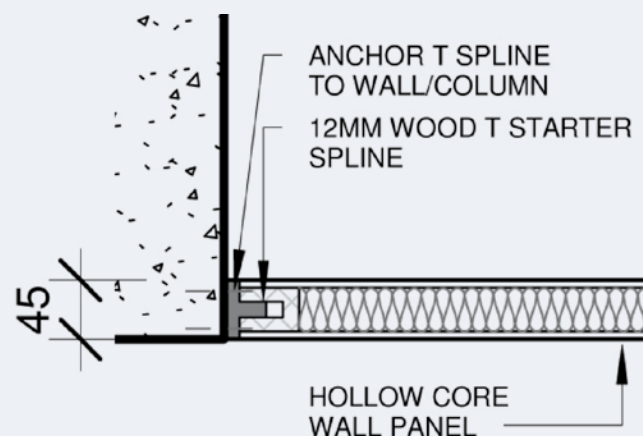


Figure 8: 'T' section for starter pieces and stop ends.

5.1.4 Channels, fixing and support

The hollow core partition needs a similar approach to the top and bottom channels used for locating partition walls in place. Two concepts can be used:

- engineered timber top and bottom channels (concept detail below), or
- extruded wood channels (such products mix waste wood fibre and resin) and can make highly detailed shapes similar to aluminium extrusions.³

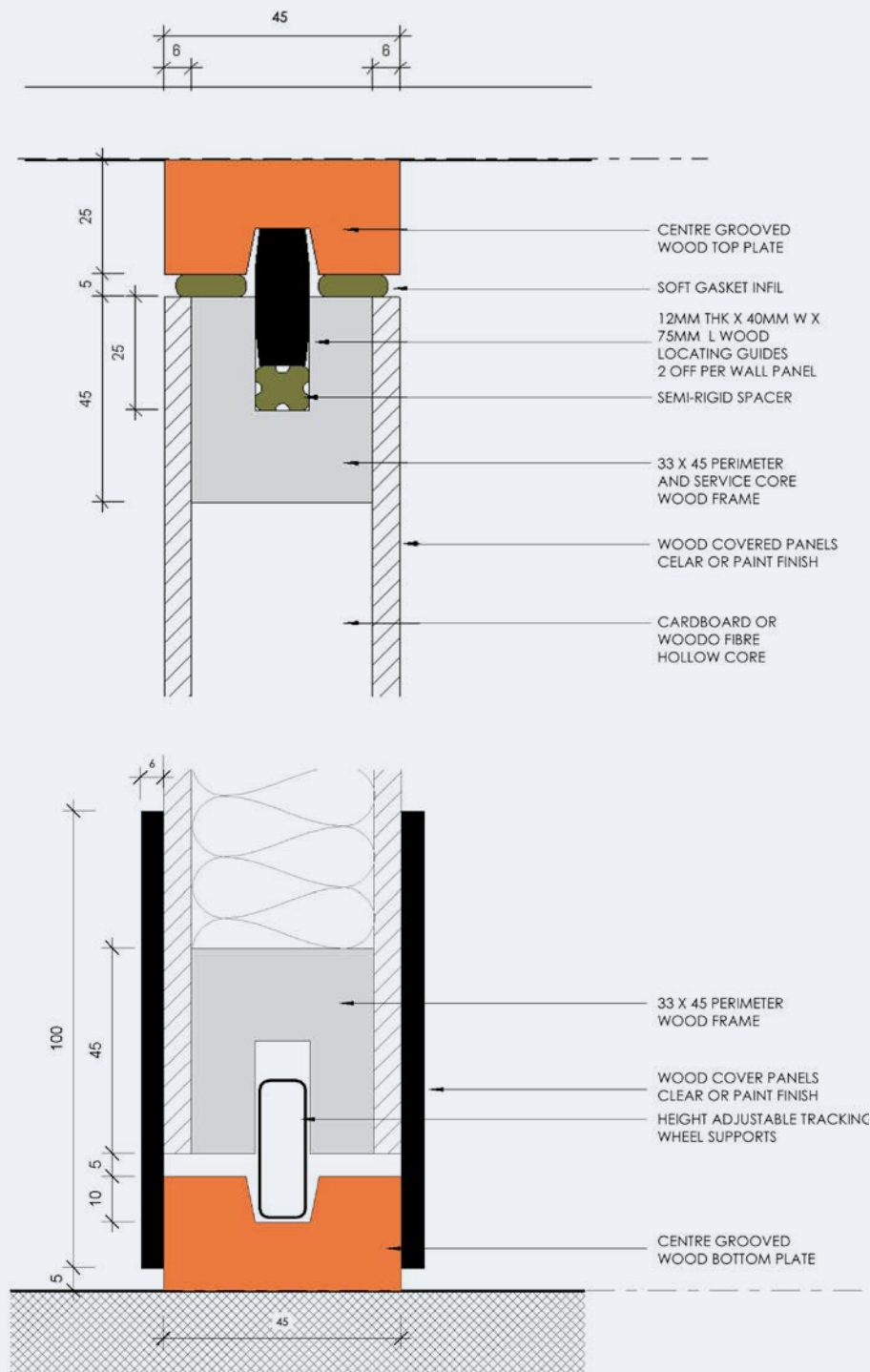


Figure 9: Concept top and bottom fixing channels utilising generic timber components (dimensions in millimeters).

³ Based on UTS design requirements, Innowood (www.innowood.com.au/), an extruded wood manufacturer, assisted in the concept development process and related the application of their products.

An advantage of the wood extrusion is that it can be ordered off the shelf or customised at much lower batch sizes than achievable with aluminium. It can be handled and worked like timber – sawn, sanded, screwed and painted the same as timber. It has a grain, colour and texture gradations that flow through the full thickness of the material appearing quite similar to real timber.

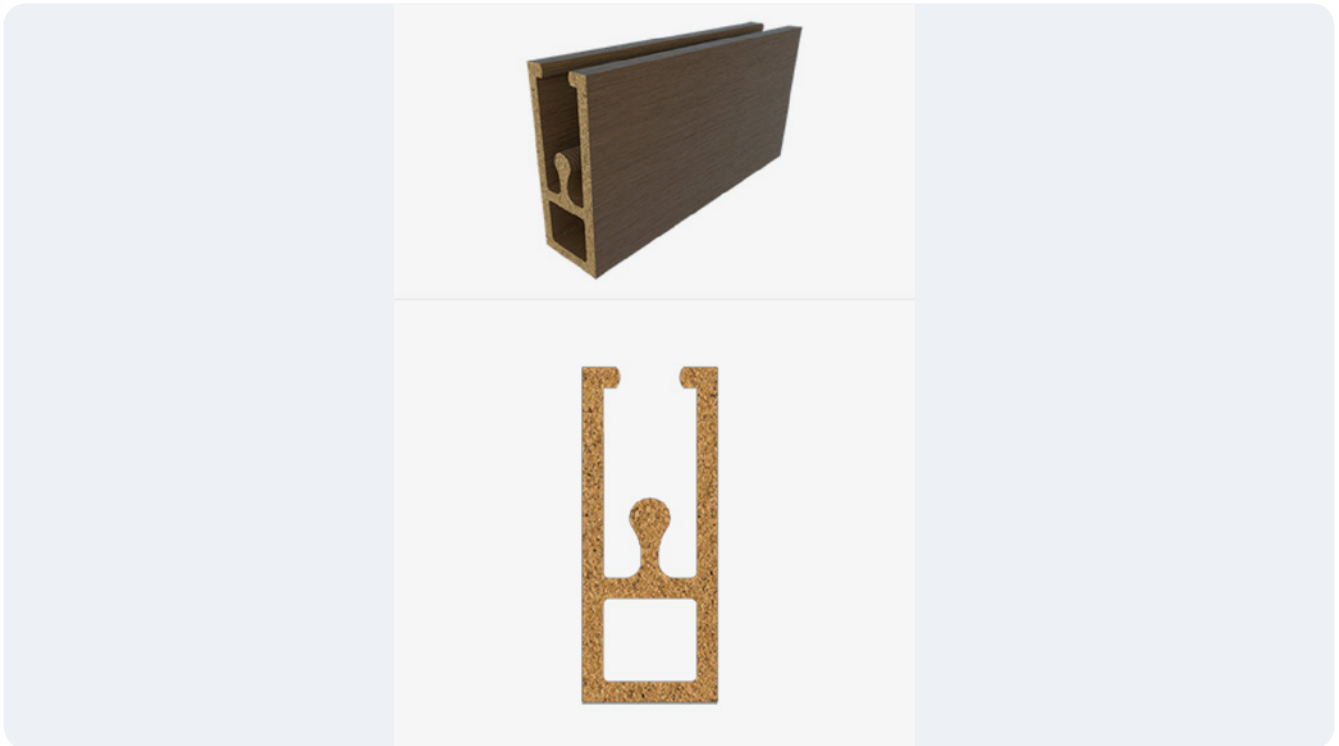


Figure 10: Example of commonly available extruded wood profile. Source: Innowood.

5.1.5 Services

The main provision for services in office fitouts concerns data and electrical cabling (including lighting and general purpose power outlets). The modular hollow core system includes provision for these services via a central void within each partition.

Minor water supply plumbing can potentially be accommodated using a similar approach. For instance, the 100 mm x 33 mm chase cavity should accommodate common water supply pipes.

Where more substantive services are required, there is the option to add a second ‘facing’ panel, which can include a dedicated services cavity between two panels. The relatively thin nature of the partitions (i.e. 45 mm) means that this approach carries a relatively minor wall width penalty that would only apply to a limited number of walls surrounding the likes of bathroom and kitchen areas.⁴

5.1.6 The wood-based hollow core design in practice

A wall in an office fitout plays a number of roles. The primary role is separation or the delineation of one space from another. There are other roles that are less obvious, but still considered in the design of the timber panel partition system:

- an enclosure for the reticulation of services to workstations or utilities
- a surface that can project an image through graphic application or material choice (veneer)
- a surface for mounting or hanging items.

The panel system uses the modular as a response to a uniform kit of parts, so the UTS designers designed a panel that can be installed on its side to become a 1200 mm high workstation partition. The panel is functional in two ways and potentially interchangeable over time if desired. As discussed later under workstations, the same basic panel concept can be used as a workstation bench top, which adds to the critical mass required to encourage reuse/recycling.

⁴ The majority of bathroom facilities are part of the base building and may not occur in tenancy-based fitout construction. Mechanical, fire and air conditioning services require separate and dedicated attention and are not dealt with here.

It is envisaged that by designing for reuse, a market will develop for the salvaged partition panels and the related components that form the overall system. The nature of these related components means they can also be supplied separately and according to project specific needs.

After multiple reuses, it is likely that the panels would be down cycled for other uses such as mulch, animal bedding, feedstock for new wood panel production and resource recovery. Specifiers need to recognise that the scope of recyclability (including door skins in particular) may be material and coating-specific and should be chosen accordingly. For instance, materials such as hardboard do not commonly include any glues where utilising natural lignin to bond the wood fibres together. Inquiries should be made with individual materials manufacturers for further details on such issues.

Figure 11 shows a general idea of the partitions as wall and workstation panels. The image has the surfaces skin removed in part, to indicate how data and power can reticulate through the panel system from the roof void down to the individual workstation setting. The image also gives an indication of the workstation design discussed in the next section.

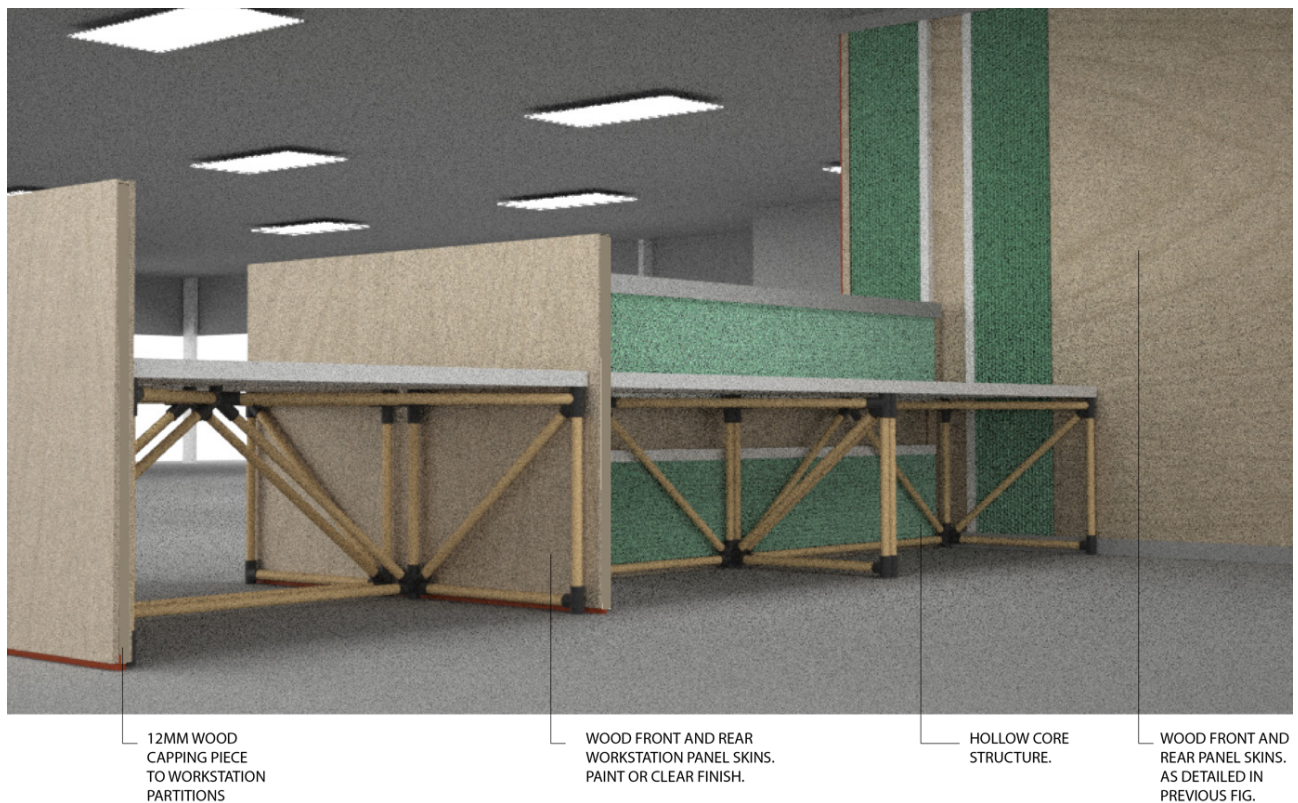


Figure 11: Concept arrangement of the UTS designed panel and workstation systems. Areas in green have the facing panel skin removed to show inner core material and service duct arrangement.



Figure 12: Partition prototype panels. Spline connector and assembly, UTS June 2016.



Figure 13: Prototype panel as a workstation partition, UTS June 2016.

5.2 Workstations Using a Reconfigurable Kit of Parts

The design paradox for workstations is that they are highly refined products, but cumbersome from a procurement and waste management perspective. For instance, they:

- have long lead times when initially purchased (often from overseas manufacturers)
- attract a large percentage of a fitout project's capital expense
- are constructed from a mix of many materials, with parts that are not interchangeable between manufacturers or between manufacturer's models
- are heavy and difficult to relocate
- are mostly worthless when they are no longer required, regardless of their condition.

Tenants nearly always own workstations and depreciate the cost over the life of the lease. The design context is driven by the combination of a near non-existent second-hand furniture market, futile attempts for disposal by the lessee, limited ability to transfer to an incoming lessee and, if all these avenues are exhausted, removed with a likely landfill destination.

5.2.1 The concept

The design questions for the future of workstations are: can they be nimble in terms of being designed to support the activities of fast-moving, constantly changing situations and can they avoid quick cycle obsolescence? These questions seek to look beyond what has gone before in workstation design and put changing business needs central to the capacity for responding to design change.

The design driver for the workstation is to afford the owner quick disassembly and reassembly without the need for specialist tools or trades people by utilising an interchangeable kit of parts and a homogenous material palette.

Steel, MDF, laminates, glues, rubber, and fabric form a common material palette of a workstation. Each material serves a role but can generally be seen as a hierarchy of material from steel as support, MDF/laminate as working surface, rubber as protective material, and fabric as image (colour). While there is a slim chance that the workstation would be relocated/reused at the end of its life, it is more likely that the combination of all these materials collectively render the system obsolete, regardless of its quality, resulting in the cost of the repurposing of a workstation being higher than the cost of its landfill disposal.

Can workstations be made less complex in their use of material and still achieve functional and aesthetic performance?

The design driver for this workstation is to reduce it to structural and functional necessity with corresponding material application.

Finally, the design considers the full extent of the life of the workstation from the time it is considered on the plan, through the changes in business activity during its use, through to the time the stripout team is assessing how they will shift a fitout from a tenancy, and beyond to alternative wood-based reuses.



Figure 14: 3D printable joiners and dowels, UTS June 2016.

The idea behind the dowels and 3D printable joiners arose from thinking about how workstations are currently made of many materials and coatings, and conversely, how far a design could be stripped back to the point of only function and material.

The goal was to employ a very limited material palette in a pursuit of high reuse/recycle potential while combining infinite size combinations. Only basic dimensions of width, working surface height, and depth were reference points for conceptual modelling.

The joiners connect the dowels at junctions and support the work surface. Removal of a few screws at selected joiners sees the whole assembly pull apart into its kit of individual parts, in minutes. Workstation partitions (see Section 5.1.6) can be added as required for privacy and other needs. Dowels can be made from decorative hardwood or less expensive softwood, which are both readily available. The printing material for the prototype joints is plastic based, but wood-based 3D printing filament are becoming more readily available.

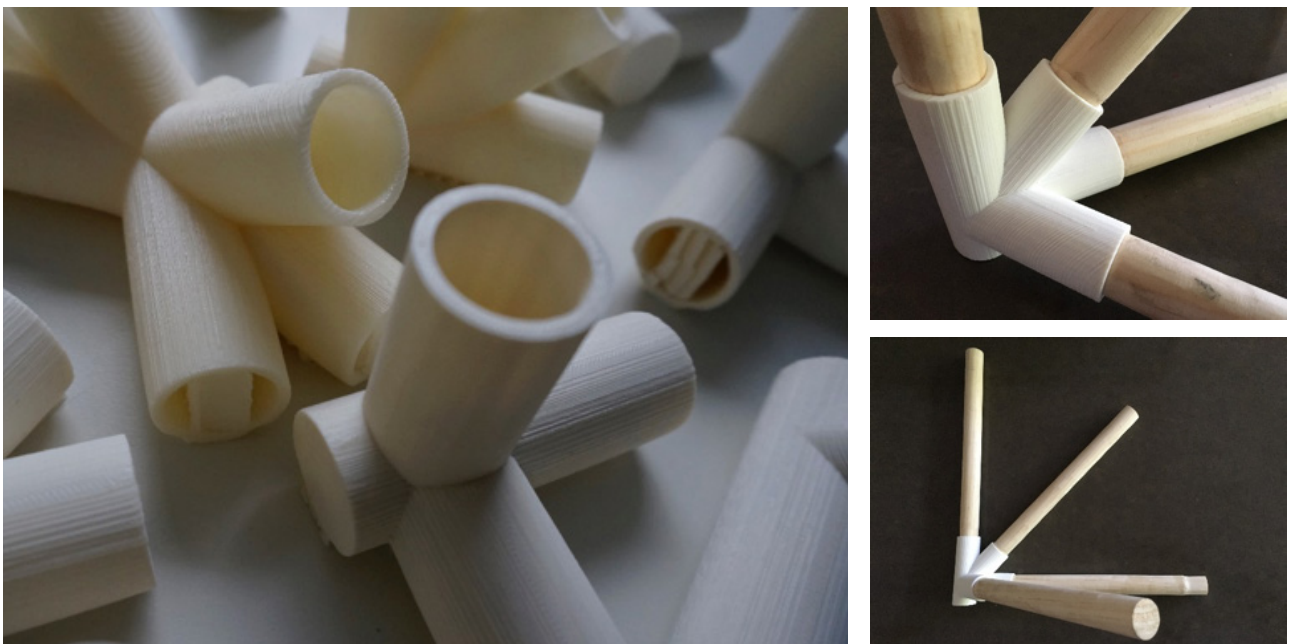


Figure 15: Printed joints, UTS 2016.

Research into 3D printed materials for frame joints should focus on structural capacity using wood filament, as this would allow for waste wood to be recycled directly back into the same product line. Further, 3D printing only tends to be practical and cost effective for small production runs but for larger projects, 3D printing should be ideally used as a precursor to larger-scale production options.

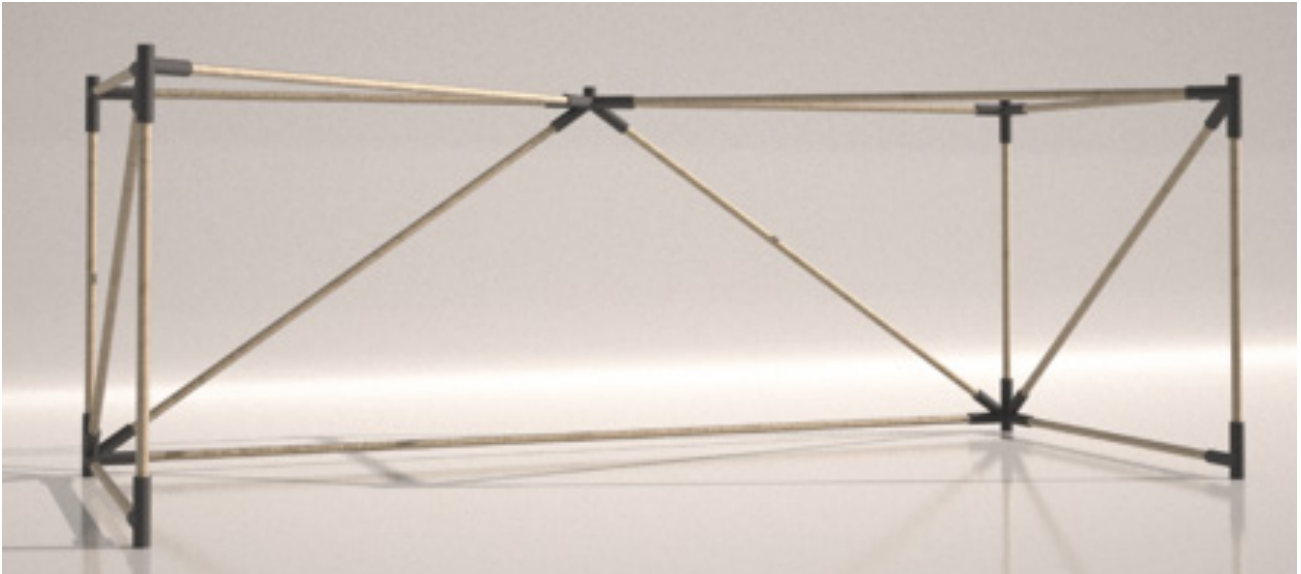


Figure 16: Concept workstation frame model (Rhino), UTS 2016.



Figure 17: Concept workstation model (Rhino), UTS 2016.

5.2.3 Details on parametric design

The design of the concept workstation was fine as a response to function, material and reuse. A designer could conceivably design a workstation by going through the same manual modelling process as UTS and print off the joiners, purchase the timber dowel members and the hollow core work surface. But this was not seen as offering the level of design flexibility required for broad-based usage. Parametric design was employed to bridge this gap by allowing continuous scalability of the work stations (i.e. the dowels and joiners). Here, the parametric plug-in (Grasshopper) was used in conjunction with common 3D CAD software (Rhino), to allow the designer to adjust the length, height, and depth of the workstation with corresponding parametric modelling working in the background. The parametric model changes the geometry of the joiners, the length of dowel members and the size of the work surface. Printing of the joints can be done directly from the software and a cutting schedule generated for the timber dowel.

To put the parametric design function into perspective, a designer could specify a number of workstation types with the joiners being automatically calculated and timber-cutting schedules generated. There is no reliance on long lead times, and possibly, workstations could be manufactured as needed when business activity changes.

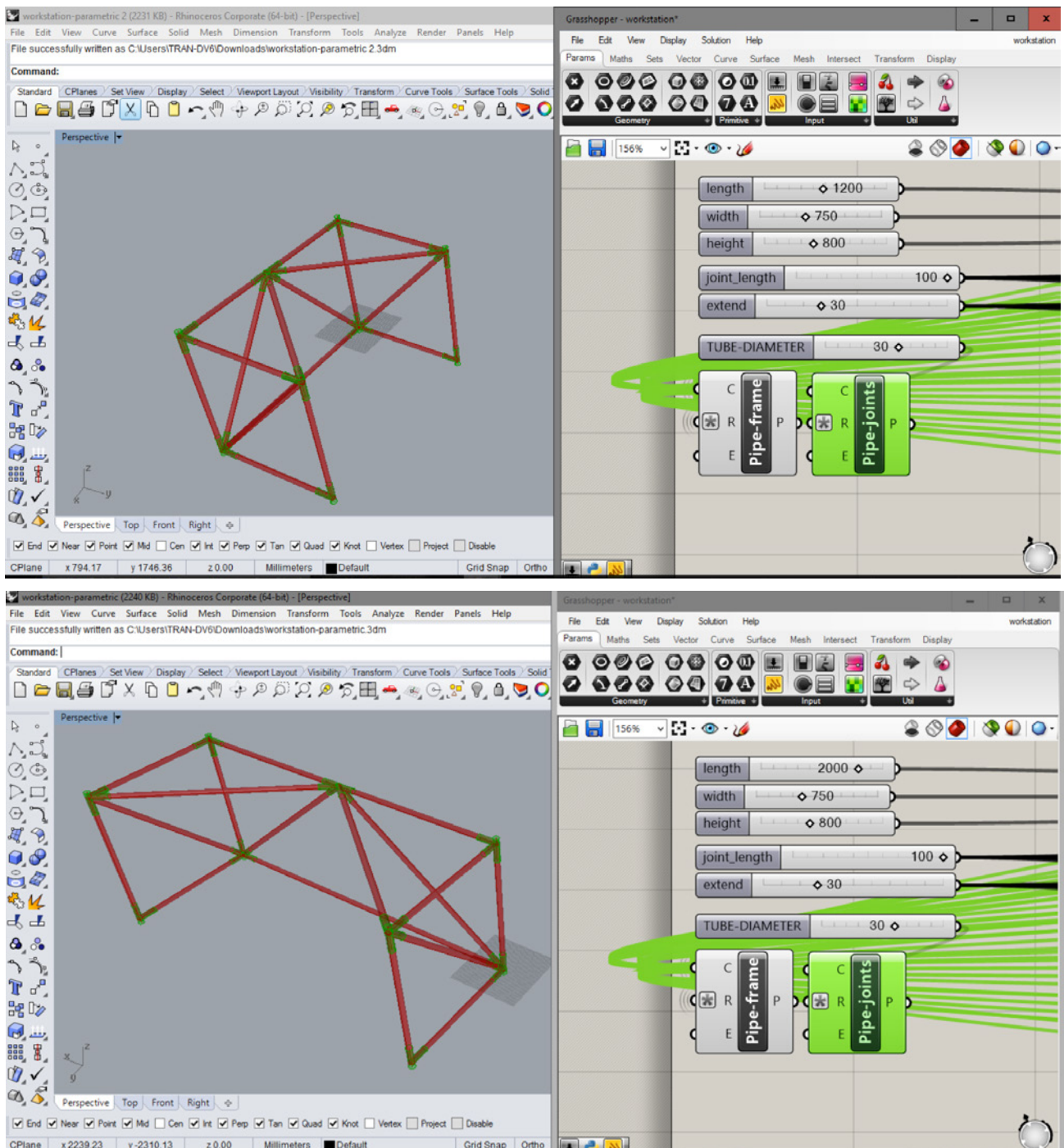


Figure 18: Parametric modelling Rhino and Grasshopper files, UTS 2016.

Ideally, the workstation design should be a web-based interface where workstations could be specified and printing files generated without the need to know Rhino or the parametric software Grasshopper.



Figure 19: UTS workstation prototype, June 2016



Figure 20: UTS workstation prototype, June 2016.

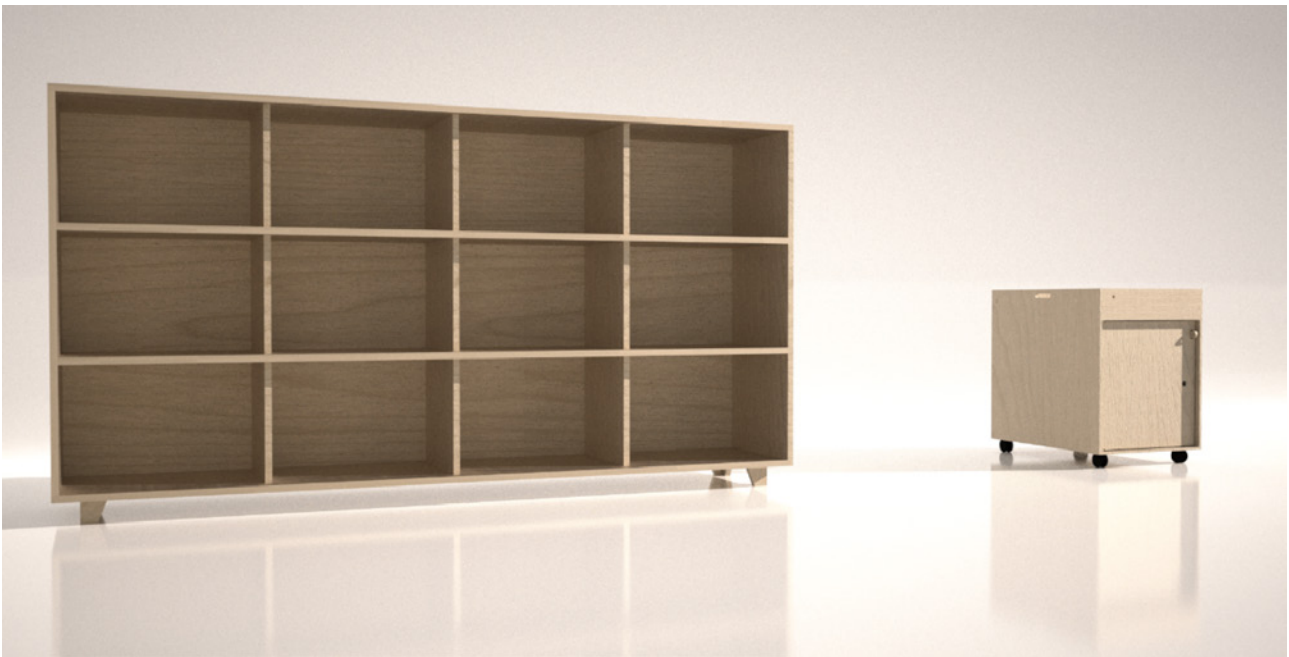


Figure 21: UTS drawing of parametric open source furniture 2016.

5.3.1 The concept

Commercial loose office furniture differs widely, depending on front-of-house or back-of-house applications.

Front-of-house is commonly viewed as a direct expression of the type and image of a business. It is an opportunity for a designer and client to showcase the nature and character of the business. Selection of this type and quality of furniture is nearly always applied to the reception area. It is quite individualistic and represents only a small percentage of the furniture and storage requirements in a fitout.

The UTS designers looked more towards general loose furniture and storage relating to back-of-house applications. This represents a larger opportunity for increased use of wood products.

General office furniture and storage lends itself to high volume repetition as it applies across the tenancy and is closely related in function and size of workstations. This repetitive nature of such furniture was found to have strong synergies with the previously discussed CNC technology. For instance, digital files tell the CNC machine how to cut the various pieces from a sheet of plywood, which may take only 10 minutes to do in practice, and then a further 10 minutes to fabricate it. Slot and tab type designs mean that there is very little need for other parts or components – even door hinges can be machined into the wood-base design that keeps things very simple for both assembly and disassembly. Here, designs for loose furniture and storage can be found as open source files on the internet. One company in particular, operates as an online studio for individual furniture designers working with wood panel products and CNC routing. *Open Desk* (www.opendesk.cc) has open source files that have been incorporated into this project. Initially, these files were used as proof of concept insofar as ensuring that CNC cutting delivered an appropriate end product. It was soon realised that by converting the designs to parametric files (see section 5.2.3), the furniture could become scalable to meet a much wider multitude of needs that could be utilised by individual fitout designers.



Figure 22: CNC made furniture by URS using *Open Desk* designs (Source: table www.opendesk.cc/zero/half-sheet-table and chair, UTS 2016, using Finn Lockers www.opendesk.cc/fin/fin-lockers#get-it-made and Zero Pedestal www.opendesk.cc/zero/pedestal)



Figure 23: Close up photograph of Zero Pedestal (Source: www.opendesk.cc/zero/pedestal).

5.3.2 Manufacturing open source furniture in practice

In terms of process, the *Open Desk* CAD files are downloaded, opened and require some work in checking for minor errors (in the jointing patterns) and potential conversion to a file type compatible with the CNC machine. The files are set up to cut pieces from a specified sheet size. Materials sourced for testing the files were readily available in plywood or other wood panel sheets.⁵ Fabrication using the routed pieces is quite fast as the slot and tab arrangements and the lightweight materials provide simplicity and an intuitive approach to assembly.

⁵ Materials used in specific parts of the CNC prototyping were supplied by Gunnersens (www.gunnersens.com.au/), one of the largest timber distribution companies in Australia.



Figure 24: CNC milling tools, UTS 2106.



Figure 25: Open Desk Pedestal manufacture, UTS CNC milling machine, UTS 2016.

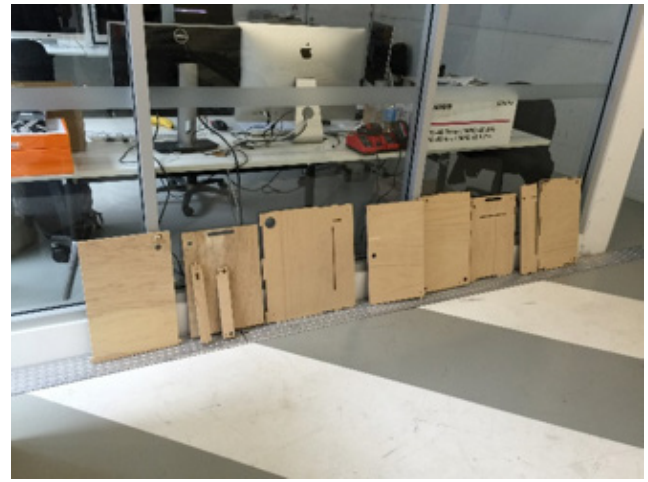


Figure 26: In-progress milling of the Open Desk Pedestal, UTS 2016

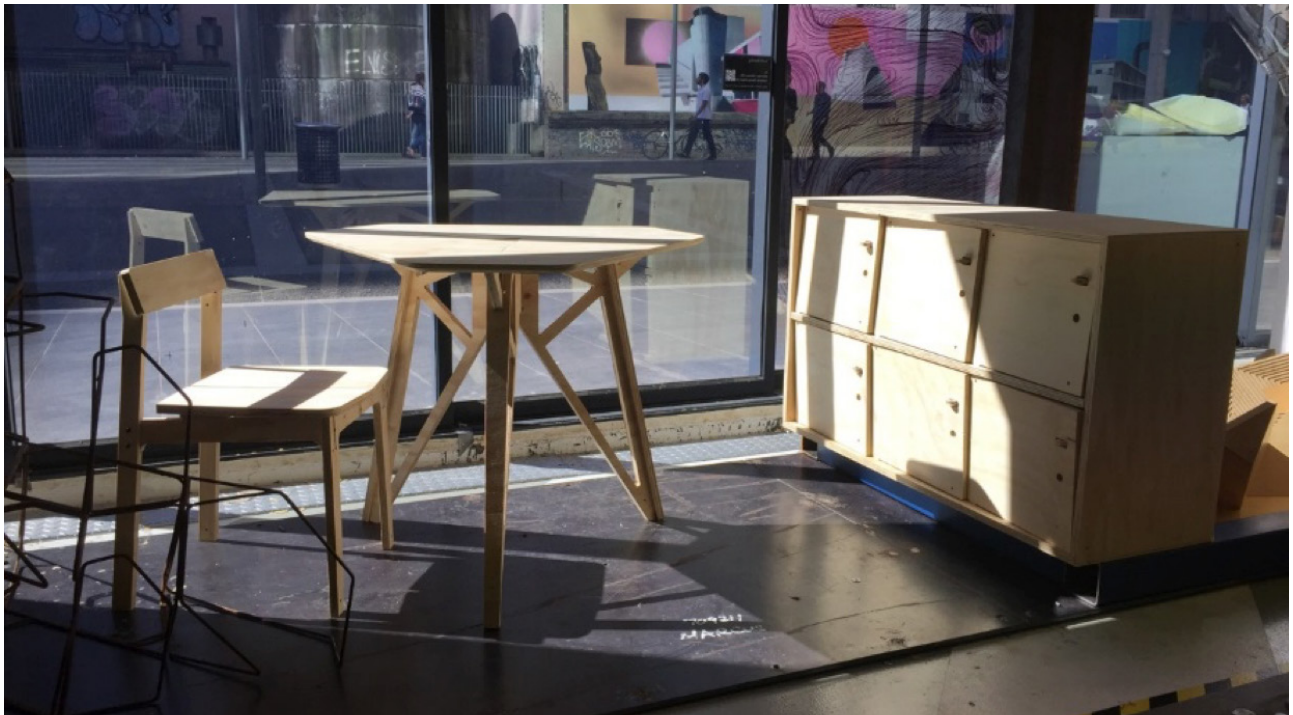


Figure 27: Completed Half Table, Roxanne Chair, Fin Storage, UTS 2016.

5.3.3 Open source products with parametric design applied

While the open source files offer access to manufacturing furniture, they do not offer flexibility in changing size to meet specific project requirements. While one option is to go back to the designer to make changes, UTS considered this as too rigid in approach for the design intention required for office fitout. Consequently, the position has been taken whereby open source furniture designs should have the capacity for user intervention. The native *Open Desk* files were rewritten in the same common software program and parametric plug-in mentioned previously (see section 5.2.3), using Rhino and Grasshopper. This approach was used to develop a select group of the open source files for storage furniture prototyping, as this was thought to have the widest applicability in office fitout situations.

The three storage units that had parametric design applied included the units shown in Figures 20 to 23. Each of these units can be adjusted in height, length, width, number of shelves, and number of dividers to suit a particular design or configuration, or respond to a number of varying workstation sizes.

5.4 Ceiling Tiles and Existing Products

Many office ceiling tiles are predominately mineral fibre products that are imported from China or the USA. They are a cheap surface that offers good acoustic performance. They are quite fragile and prone to breakage and water damage. Plywood products have potential as an alternative and should be considered where resilience, aesthetics and potential reuse capacity come into play or where ceiling tiles provided as part of the base building, remain in place from one tenant to the next.⁶

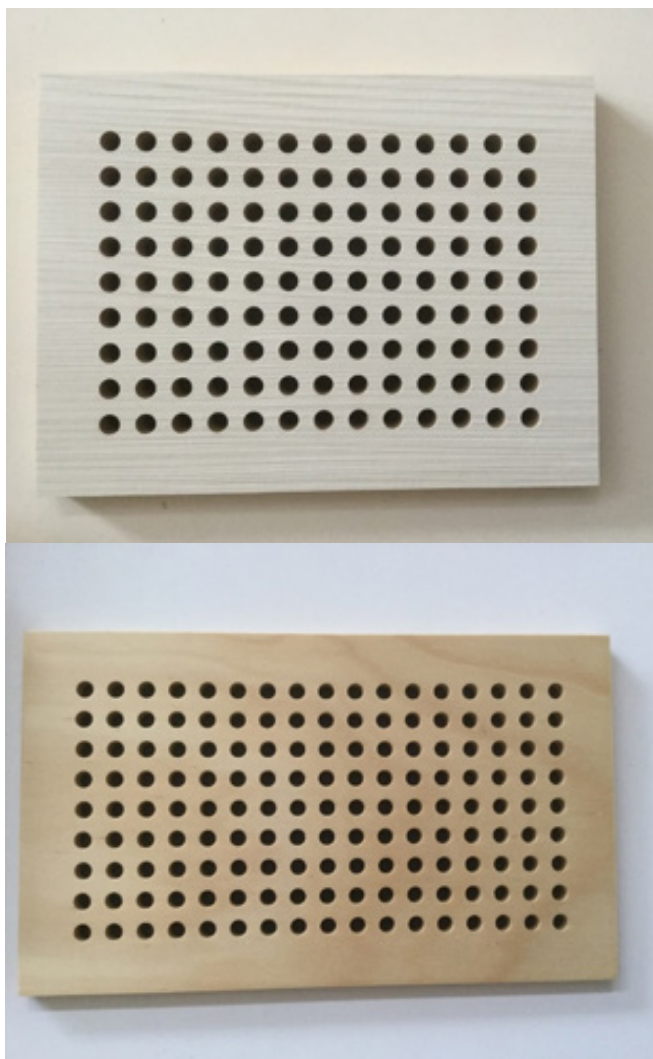


Figure 28: Ceiling tile example.
Source: www.keystoneacoustics.com.au/key-plyKey
Lena Sample, 2016.

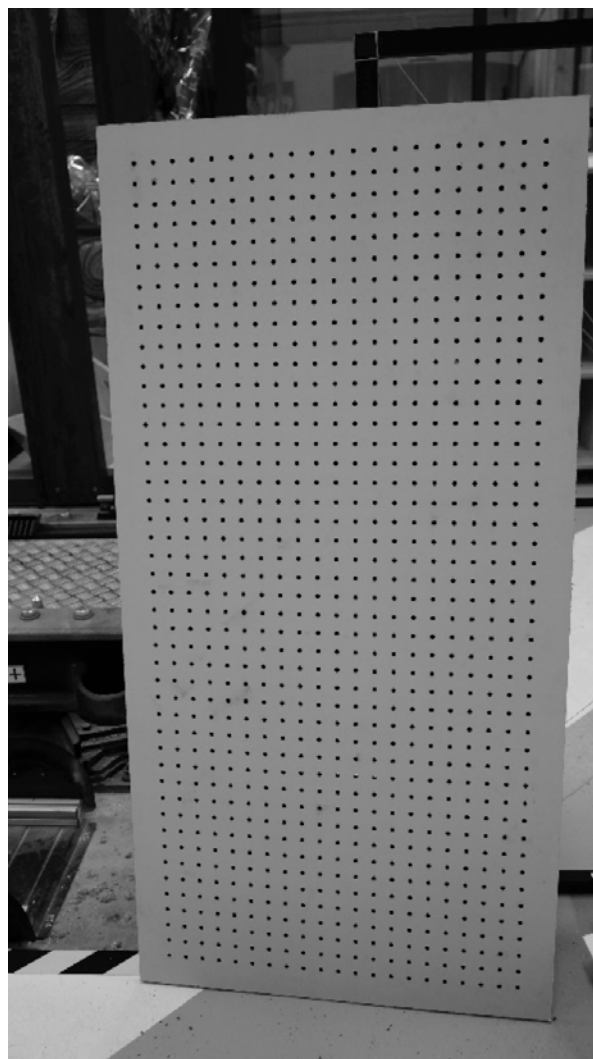


Figure 29: UTS CNC milled hardboard 1200x600 ceiling tile, UTS 2016.

⁶ UTS manufactured its own standard 1195x595 mm ceiling tiles from 9 mm hardboard. While this material exhibits good recyclability potential – due to using natural lignin as a binder instead of glues – machining properties need to be improved as machining of slots and holes tends to result in furry edges.

6 A Life Cycle Assessment Comparing Wood-Based and Traditional Fitouts

Building on the previous description of wood fitout concepts, the concepts were compared with traditional office fitout to determine if any environmental benefits existed. The most appropriate and accepted method used to holistically assess the environmental impacts associated with a product – including construction products – is Life Cycle Assessment (Cole 1998; Junnila, Horvath & Guggemos 2006; Horne, Grant & Verghese 2009).

Ostensibly, the study used a typical 1,550m² floor plate to model both options (Figure 30). From this, materials, production and end-of-life processes were quantified to determine amounts of life cycle energy and greenhouse gas emissions (GHG) for each option. While the wood approach utilised the aforementioned designs, the traditional approach utilised steel stud and plasterboard partitions; aluminium and glass partitions;⁷ a mix of suspended plasterboard ceilings tiles and decorative aluminium tiles in selected areas; workstations with MDF tops with metal support chassis. Of note, floor coverings were predominantly the same for both options and therefore represented a neutral variable in the comparison. The study is detailed fully in the parallel research report to this guide, 'Increasing Wood-based Office Fitout for Sustainable Life Cycle Benefits' (download at www.FWPA.com.au) – only key findings from this report are provided here.

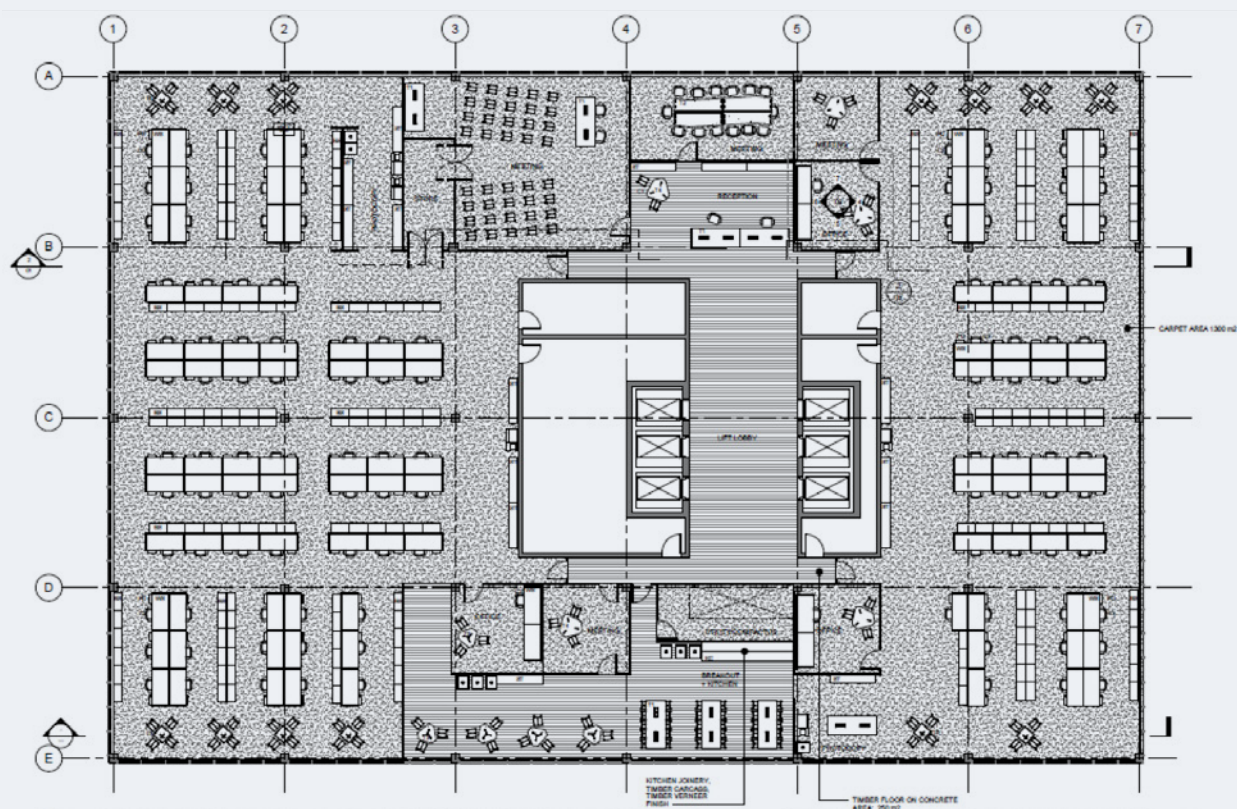


Figure 30: Hypothetical office space used for wood versus traditional LCA comparison.

⁷ In the wood version, aluminium extrusions were replaced with timber profiles.

Drawing from the report findings, the traditional design consumes about 1,565,300 MJ or 1,009.8 MJ/m², while the wood-based design consumes 1,321,900 MJ or 852.8 MJ/m². The traditional approach therefore consumes about 16% more energy than the wood-based design.

Reading from Figure 31, the main areas of dominance concern the wood-based office furniture and partition walls. Here, office furniture consumes 195 MJ/m² and 103 MJ/m² respectively for traditional and wood-based design. Traditional office furniture consumes about 47% more energy than wood-based office furniture. Wood-based design of internal walls also provides a significant reduction in energy consumption – traditional represents 122 MJ/m² and the wood-based approach 80 MJ/m², a reduction of about 35%.

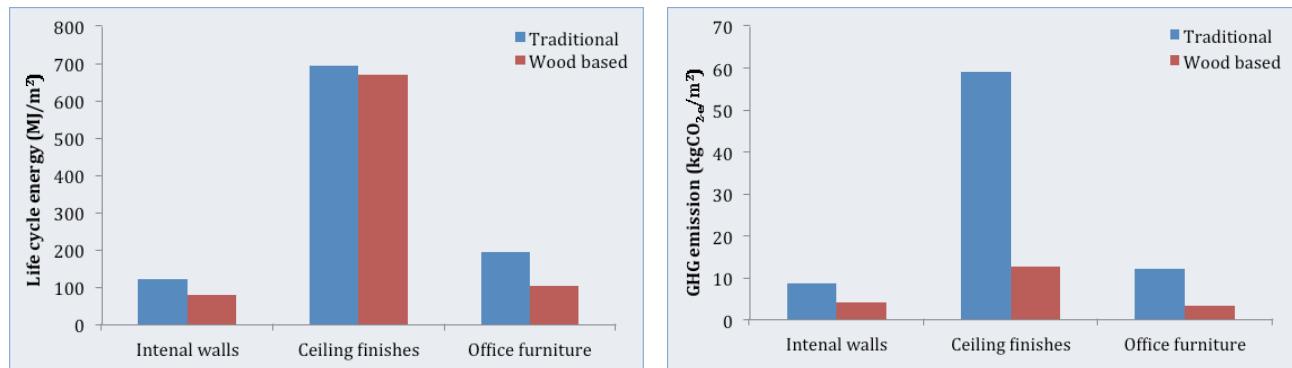


Figure 32: Comparing wood-based and traditional fitout designs.

With regards to GHG emissions the traditional design emits about 124,100 kgCO₂-e or 80 kgCO₂-e/m² compared to 31,400 kgCO₂-e or 20 kgCO₂-e/m² for the wood-based design. The traditional design emits about 75% per NLA more GHG than the wood-based design. The materials used in the traditional design, such as aluminium, steel and glass, are highly polluting materials that emit a high content of GHG during manufacturing processes. The traditional design of internal walls using metal stud and plasterboard emits about 54% more GHG than the wood-based partition panels. In addition traditional workstations and pedestals also emit about 72% more GHG than wood-based office furniture.

Given the above, key areas for life cycle improvement – where the wood-based approach improves on the traditional approach – include workstations (including wood instead of metal chassis) and partition walls (including hollow core panel walls).

7 Conclusions

The design concepts in this guide offer a canvas of production possibilities where it must be realised that the value of the material cannot be separated from the product. The designs particularly focus on partitions, workstations, furniture and suspended ceiling tiles. Key conclusions include:

- Workstations appear to consume the most significant resources and material mix. The strategic conclusions are to reduce the material palette to one material (wood-based products), a small kit of replaceable parts that could be used over, be of a material that does not rely on long lead times and could be made using a just-in-time approach.
- Collectively, there is not enough critical wood mass (that is sufficiently homogenous in terms of material type) to stimulate reuse and recycling markets. Increasing critical mass is important in order to make reuse and recycling economically viable during stripout processes.
- The design and construction industry employ established products and systems that are very familiar across the industry to designers, construction and stripout contractors. This report has cast construction and furniture systems in a different light by creating and discovering other construction methodologies that could benefit the industry.

Key benefits associated with the design concepts in this guide include:

- A significant increase in the use of wood products.
- A reduced material palette across all fitout items, focusing on a more homogenous set of wood-based materials.
- A significant simplification of construction methodologies across all fitout items that do not rely on mixed materials and metal fixing.
- A reduced number of trades involved in fitout.
- Workstations that can be made to order without the reliance on a lengthy ordering process.
- Workstations with components that can be easily disassembled and reassembled.
- Designs that are open source, including workstations that have parts that are not specific to any manufacturer's system.
- Designs that suit a furniture-driven approach to fitout that is well suited to open plan office designs.
- Reduced life cycle energy and much reduced GHG when compared to traditional fitout (especially for workstations and partition walls).

Even though this guide takes fitout design into a new mindset, the concepts are not reliant on each other and therefore allow individual uptake. The approach is also progressive in terms of taking advantage of the way wood lends itself to new digitally driven forms of production such as Design for Manufacture Assembly and Disassembly. Future work should consider developing this approach further and merging it with other arising technologies such as the Radio Frequency Identification tags (RFID tags) – already commonly used in retail and transport logistics. These tiny tags allow small amounts of digital information to be stored in the likes of furniture assemblies and can wirelessly read/write information, thus making it possible to track and store reuse, recycling and sustainability information for a given product both during, and up until end of life. This provides a systematic way to verify the sustainability of wood products.

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