Criteria 5

Valentino T'Blaxill

Criteria 5:

Wood finishes:

User centred design:
Water based varnish leaves no strong fumes once applied unlike resin style varnishes which for a few weeks after application put of a strong chemical smell. This is important as it will be applied in a tight living area and the strong spell of chemicals is unpleasant and may prevent the end user from using the product immediately after completion.

Wood finish: Shellac
Shellac is a natural resin based finish which is made out of lac bugs of southeast Asia. These bugs secrete a natural resin that is used in this product. Shellac is a very old finish and has been used in furniture for hundreds of years. The advantages of shellac are that it is nontoxic with no fumes which is important as the user van is a small space and if the finish has a strong fume it will be unpleasant for the end user which will lead to less use. Shellac is also easy to work with as it is fast drying and can be applied by spraying or brushing. Shellac is easy to repair as you can simply apply another top coat layer on the affected area this might come in handy if due to the harsh use it might need a refresh which could be easily done. There are some disadvantages that include the fact that it is easily removed with any type of alcohol which will result in decreased durability. Shellac is also not suitable for hot items as it can leave rings and marks which is not ideal as it will hold kitchen items and I am sure will be used to hold a hot drink.

Purpose function:
Water based varnishes are easy to apply as they have a high solid content which makes them build up quickly and you get thick coats which gives the wood added protection. After use it is easy to clean up and it does not affect the colour of the wood leaving the natural grain and colour.

Visual tactile and aesthetics:
Compared to water based varnish solvent based varnish gives the wood a deeper and darker colour and leaves a very shiny and glossy finish.

Figure 10 Polyurethane varnish(solvent based)

Sustainability:
Water based vanish is far less toxic for the environment when compared to polyurethane varnish. This is relevant as my users views sustainability as important and that how bad for the environment a product is should be taken into account.

Figure 9 Water based varnish

Figure 11 Wood staining

Purpose and function:
Polyurethane varnish is very durable and is easy to apply. It is resistant to heat, chemicals, water and wear and tear such as scratches and scuffs.

Another finishing method is staining the wood with a clear coat. This enhance the woods finish and highlight its natural wood imperfections and grain. This is a relatively inexpensive finishing process as it is very simply, as well as giving the product a highlighted aesthetic it makes the wood more durable and water resistant this is important as the product will be exposed to use in a variety of climates and might come in contact with water. (TRIANGLE KITCHEN LTD, 2017)
A different style of wood finishes is the use of a veneer if the bass material is not the most aesthetically pleasing a thin layer of a desirable wood can be glued over it to give that particular species look and finish. With this thin layer you also get added protection and durability if you use for example a hardwood based veneer. This is a solution to getting the look if an expensive timber for a cheaper price as only the thin exterior of the product is made out of that wood. (Sharp plywood, 2018),

User comment: "I like the natural finish shellac however I am concerned on how durable it will be and as it can come in contact with hot items it might pose and issue. I would prefer to use the water based varnish over the poly base due to the fumes that come from poly based finishes. I don't think that using a veneer over the wood will be a solution as it adds more weight and does not look as good as real good quality wood I would rather pay slightly more form a high grade plywood than cover a low grade wood with veneer."

Materials:

(Structural plywood vs Non-structural plywood)

The Main differences in these two types of plywood is the type of glue used in the construction of the plywood boards. Structural plywood use a A-B bond types of glue. These are made from a resign which will create a glue bond that will not weaken if exposed to wet conditions as well as temperatures. Non-structural plywood falls under the C-D bond types. This means that they are produced from a resin which is not suitable for structural use as well as outdoor use as the glue deteriorates when it is exposed to wet condition and heat. To fulfil my users requirements I believe structural plywood has characteristic and properties that will ensure it can withstand the regular use and will work better in this application.

When selecting plywood it is important that it has a FSC certification which means that the material used to make it has been sourced from sustainable regions instead of endangered tropical forests or illegal sources, this is in line with my users sustainability statement and also means the end product will have less of a negative impact on the environment. (Decorative hardwoods, 2018)
Premium Birch plywood is a viable option from ply co. It comes in 2440x1220mm sheets in a variety of thicknesses and has A grade front face and B grade back which is ideal for the application it also complies with FSC certification adding to its sustainability. Birch plywood has a warm/light coloured appearance and fine grade detail which adds to its aesthetic quality.
It is also very assessable with many suppliers selling this product resulting in reduced wait times.

User comment: "Structural plywood looks fantastic and the properties of the construction lend its self to the project. Cost is in budget and FSC ticks the sustainability box. Non-structural ply might not stack up as well to the rig gurus of van life."

Suitability rating: 5/5

Particle board:

Particle board has many desirable properties these include, its weight to density ratio which is achieved through its manufacturing method this is important as my user has requested that the material be reasonably light. Another property is its fire resistance which can be achieved by adding a thin layer of melamine this is relevant as it will be holding cooking items including a gas bottle and in case of an emergency might give the user a few seconds to either get out of reach for the fire extinguisher. Another attractive property is that particle board is made from mostly eco-friendly materials as it is composed of mainly recycled materials and waste such as wood chips, wood shavings and sawdust. However being made of these weak materials does take its toll on strength and therefore particle board cannot support heavy loads and if is exposed to moisture it can cause swelling which leads to cracking and failure in the material. This is not ideal and does not meet my users constraints as the material must be durable and able to be used in varying conditions. A further negative to particle board is its aesthetic as it is made of cheap materials and has not natural grain. Another disadvantage of particle board is that it has the tendency to warp in heat which might be an issue as the inside of cars gets hot when left in the sun and this warping might leads to additional stress on joints and misalignment of draws and fixtures. So overall this material is not ideal as it is not best suited to the operating conditions that it will be exposed to. (Gharpedia, 2018), (Gunnersen, 2017)
Same as plywood as having a large supply.

Suitability rating: 1/5

User comment: "Particle Board ticks some of the box's and I like the melamine flame resistance, but might not stand up to heat/wet fluctuations of van life. Weight might be an issue as well."

EKOply:

EKO is a recycled plastic plywood alternative and is very similar to ecosheet these materials are made out of 100% recycled plastics which would typically end up in land fill making them very sustainable which is in line with my end users sustainability statement. EKO is very hard wearing and is weather proof as it is a polymer based material this is an attractive characteristic as it complies with my users constraints and will be suited to the environment that it will be used in. EKO is also a lot longer lasting then typical timbers as it cannot rot or degrade naturally. It has similar properties as timber such as it can be cut and screwed in traditional ways which makes it easy to work with and time efficient. The material needs no coating added to it to preserve it like timber would making it economically viable and simplifying the production process. This is an example of a new material which makes the product innovative and unique which has been requested by my user. One major negative to this material is its aesthetic as it does not have a natural look which has been requested by my user. (ecosheet, 2019), (SLPW, 2019)
Unlike plywood, MDF, TAS oak and particle board EKO is harder to find as it is quite a new material and hasn't made a huge market in Australia yet so you would have to import from England which leads to increased weight times and increased price due to shipping.

Suitability rating: 2.5/5

User comment: "EKOply wow never knew this was a thing and what a product. Strong, light, eco-friendly and made from waste. If a natural look wasn't a requirement this would be a strong contender."

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MDF board:

MDF is short for medium density fibreboard which is a man-made wooden material commonly used in furniture and building. MDF is made from wood fibres glued together with the aid of heat and pressure. As of this prosses MDF has no natural grain which makes it significantly easier to saw as it is lacking any knots and grain. This makes it easy to work with which makes it time efficient as well as making the cut edges very smooth which gives the end product a nice clean look where other materials may require extra sanding to get that same finish. MDF is very cheap which helps in keeping the product price under the budget. MDF has some desirable characteristics such as great strength and stiffness however due to the high glue content it can be heavy and blunt tools quickly. The fact that it is very heavy makes in not ideal for the application as my users constraints outline that it must be light weight as to not affect the vans performance. Another negative is its aesthetics due to the material having not natural wood grain so you would have to cover it in paint or stain which adds another process and added price. (Odum, 2018)
Can be easily ordered in with it being a very common material used it cheap furniture and DIY.
MDF is also not allowed to be used in Australian schools as the dust created when cutting is very fine and can cause respiratory system problems for this reason this is not a viable material option.

User comment: "MDF is rubbish toxic and the very lowest common unit."

Suitability rating:
1/5

Oak, Tasmanian:

Tasmanian oak is a premium Australian hardwood and is commonly used in building, flooring and panelling. Tasmanian oak is light in colour and has a beautiful aesthetic when finished with a light varnish or clear stain. This is appealing as it will make the product have a high quality look and will appeal to my users constraints under visual, tactile and aesthetic. The fact that it is locally sourced means the products distribution distance is relatively small meaning it has less of an environmental impact which is in line with my user sustainability statement. Tasmanian oak is very strong and durable with it average inside life around 15 years which makes it ideal for its application. The only real negative to this material is it is slightly expensive compared to the others and might not be able to be used due to the limited budget. (wood solutions, 2018)
TAS oak can be slightly harder to source but has many suppliers that hold stock and is not as hard as EKO.

Suitability rating:
4/5

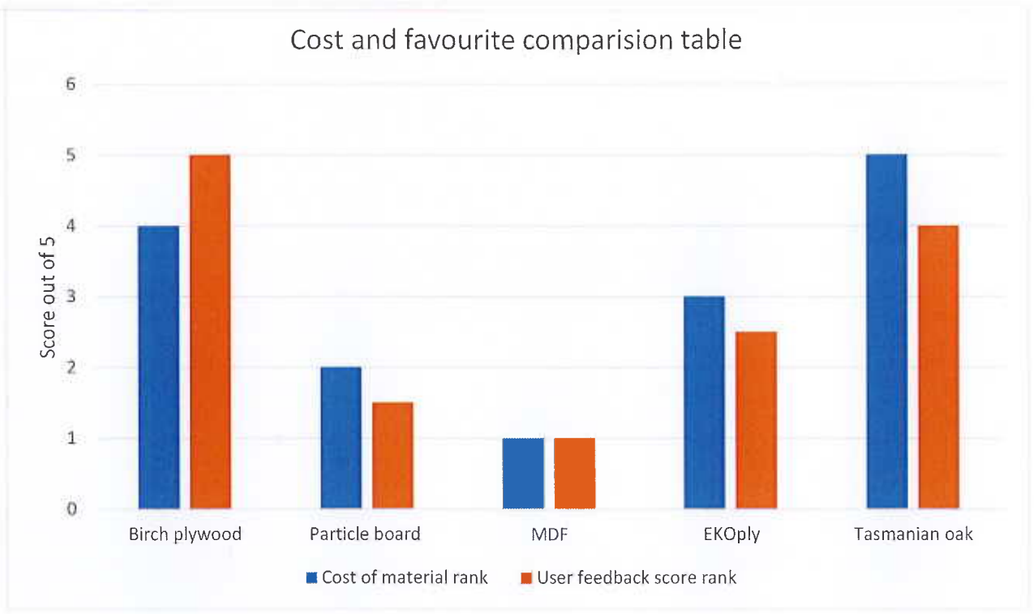
User comment: "TAS Oak has all of the requirements bar price. Perhaps elements can be highlighted with structural ply to enhance design cues."

Cost comparison Table:

Material:	Birch premium plywood(PlyCo) 12mm	Particle board Min(12mm)(PlyCo)	Standard MDF 9mm(PlyCo)	EKOply 12mm (Ray Grahams building)	Tasmanian oak 9mm(apex)
Cost: per sheet	Size: 2440x1220 $170.46	Size: 2400x1200mm $32.16	Size: 2400x1200mm $25.66	Size: 2440x1220mm $125.55	Size: 1220x1220mm $189.00

As shown from this price comparison the less aesthetically appealing and materials with non-desirable characteristics and properties are the cheapest with the exception of EKO. This can represent their production cost and quality. EKO seems relatively well priced however this price does not take shipping intentionally into count which will increase the total price. As shown nice aesthetics comes with a price in terms of TAS

oak. From this data I believe that the best option is Birch premium plywood as it has the best value for money due to its nice aesthetics and appealing properties and characteristics to which my end user has agreed with.



This table shows the comparison between each material researched. The orange column is a rank out of 5 given by the user and has greater weighting compared to blue when it comes to selecting a material. The blue column ranks the material from most to least expensive with a score of 1 being the cheapest and 5 being the most expensive. Whilst it would appear that MDF scores best in this category it also has a very low user rank is has greater weighting. From this data it can be conclude that Birch plywood is the most suitable material.

Joint research:

Finger joint-

- This style of joint is strong especially when used with a good glue such as pva. This strength is due to the joints interlocking style. This makes it very hard to pull apart and gives it great rigidity. The finger joint is also aesthetically pleasing as it shows the side grain of each of the pieces that are being joined. This is important as my end user needs the product to be strong whilst also looking good which the finger joints fulfils.
- To test the quality of a finger joint you measure the gaps between each interlocking piece the smaller the gap the better the joint with a perfect joint have no gap.
- The disadvantages of this joint are that it can be hard to align and ensure that the two pieces of wood are flat and not crooked and it is also a time consuming job if you are doing it with hand tools however can be easily done through the use of a finger cut router bit as seen in the image.

User comment: "I like this joint it has a nice aesthetic and seems to be pretty strong which is important in the project. My only worry is that it might be time consuming and might be hard to repeat with accuracy."

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Butt joint-

This joint is very simple and easy to make, there are two pieces buttered against each other at right angles. This joint is very weak and when glued can be easily pulled apart with your hands. This joint is not very aesthetically pleasing and will not be well suited to the project. https://www.thesprucecrafts.com/wood-joinery-types-3536631

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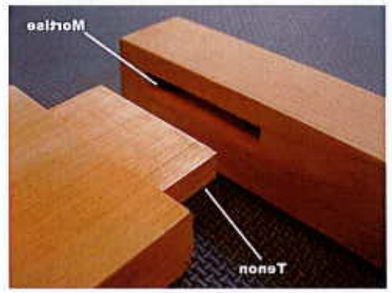
User comment: "I do not think that this joint is up to the task unless there is reinforcement behind the joint. Not a personal favorited. However it could work well and be stronger if it was also held together with screws."

Mortise and tenon-

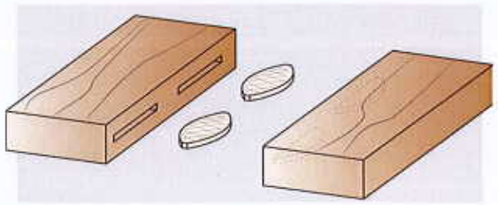
- This joint is great for corner joints and gives a sturdy and strong finish. This joint gives a clean look forms an elegant joint. The only negative is that the joint can be hard to master and you must follow a certain ratio for the thickness of the wood to avoid the any splitting of the mortise which would lead to the joint breaking.



User comment: "I like both the M&T and biscuit joint however I can't see how these would be used in the cupboard as there won't be an internal fame which would require a M&T and the outside panel will be one piece which won't require a biscuit joint to connect them."

Biscuit joint-

- This joining prosses uses a thin beechwood wafer know as a biscuit to sit in-between the two pieces of wood that have the required groove routered into them. This is a very useful technique when making table tops of large flat pieces of timber if you don't what to produce the product from a sheet style timber like plywood. This joint relies on glue and the swelling of the beechwood biscuit to hold the boards in place. The cut that is made into the two pieces of wood is make possible through the use of a biscuit cutter tool this insures that the cut is to the correct dimensions for the biscuit to expand and form a tight hold. An advantage of the biscuit joint is that you can cut in the groove so that there is a bit of movement back and forth this aids in lining edges up and results in an overall clean finish.



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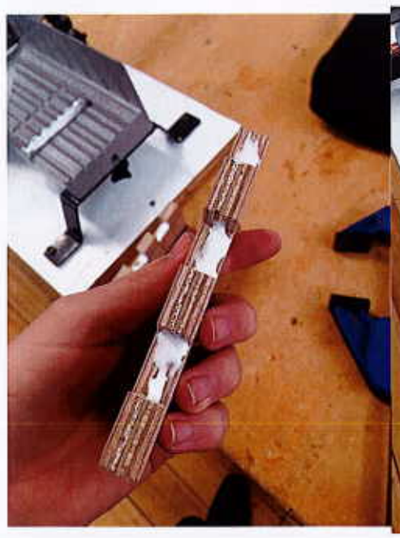
Process testing: Joints

Finger joint:

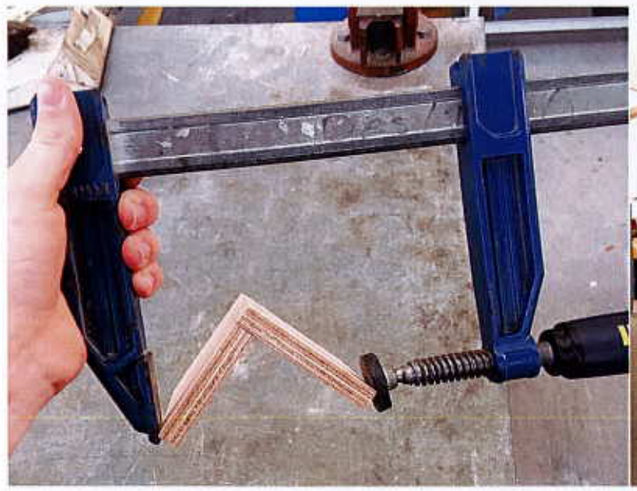
First step is to accurately mark out the finger joint using a ruler and carpenters square to ensure quality and accuracy, ensure all your lines match up and that the depth of each finger is the same as the thickness of the wood.

Next I used the Hegner scrollsaw to cut out the sections marked with a X. I made sure I cut dead on the line for each piece to keep it consistent and make the end joint align better. I made sure the blade had good tension so that I couldn't get wavy lines when cutting ensuing a quality joint.

After cutting out both pieces I made a dry run to make sure my clamping locations would work and that the fingers align nicely with minimal gap. This dry run before final assembly ensured that I knew the correct orientation of the pieces and that I don't make any mistakes when using glue. This again insures a quality joint which is important as it will be subject to strength testing after completion. As you can see from this image the aesthetics of this joint are nice and shows the side grain of the wood.



After trail dry run the next step is to apply pva glue to the inside of each part of the joint. Make sure to spread out this glue to get even coverage for maximin strength. Once glue is applied quickly assembly the joint and apply pressure through the claps to push all of the excess glue out. Use a damp paper towel to remove the excess glue which will be easier now than when sanding.



The next day after the glue had had 12 hours to set I test the flex and structural integrity of this joint by applying force on each corner using a clamp as you can see from this photo under a reasonable force there was no flex and the joint did move at all. This was also tested with me standing on it weight(70kg) which didn't show any signs of wear or breakage after this test.

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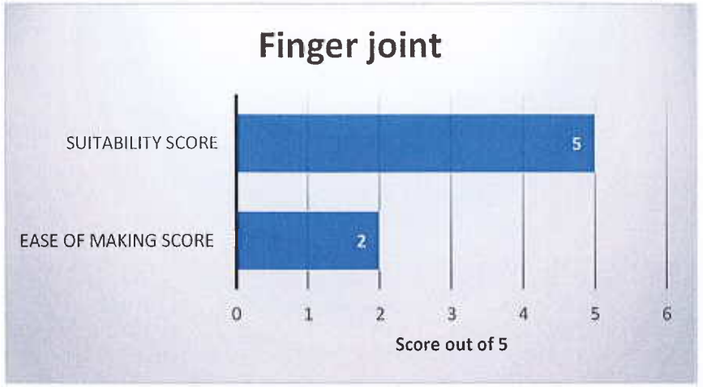
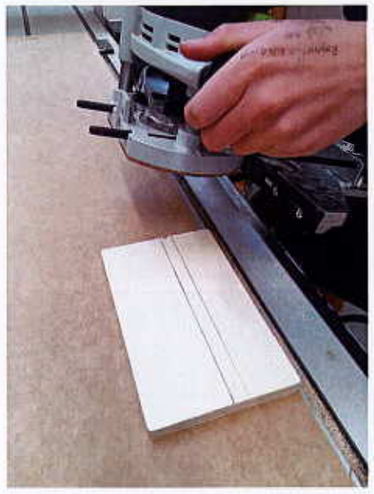
The final test on this finger joint was an elasticity and final test until destruction. The elasticity test measures the bend of the joint as a load is hung of it. As shown in the image a bunch of weights 9.7kg net weight was hung of the joint while the other side was held in a vice. There was very little to no flex. After this I added another external force in terms of a hammer and with the weights hanging and a solid hit from the hammer the joint gave way however the point of fail was not the joint instead the material as the plywood started to delaminate. Another factor to take into consideration is the fact that this was just a right angle joint and if it was a complete square it would have a lot higher rigidity and I would struggle to break it. We can conclude from this test that the primary tests support the secondary research on this joint and that it is very strong and has a nice aesthetic and for those reasons I will try and implicate this joint in my design.

User comment: "I like how well this joint preformed in the strength test and it has nice aesthetics"

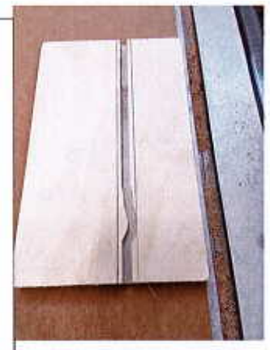


Through housing joint:



The first step is to accurately mark out the sides of the groove using a ruler and carpenters square. The material I used for this joint was 12mm so I made this channel 12 mm wide. The next challenge when making this joint was to ensure that the piece of plywood was clamped down securely and there was a straight edge next to it to run the router guide along to ensure a straight cut. I came up with the solution of using the suction from the cnc router table to hold the piece of plywood secure whilst cutting. This worked out well as you couldn't use a conventional clamp as it would interfere with the router guides. As this was a small piece of material there was not much surface area and it wasn't holding it down enough so Griff closed off on side of the suction table so there would be a greater suction force which worked well. In this image you can see me setting up the length of the guides to make sure I was in the middle of the two outer lines and also the depth of the cut at 6mm.

After you have set up all of the guides correctly and are happy that it is aligned turn on the router so that the "bit" is just of the wood not on it this will ensure safety and will mean the wood won't try and move. Once the router bit is spinning mover it across the wood slowly and steadily whist keeping the guide hard up against the reference edge of the table. This was the first time I had used a machine like this and towards the end of my cut came a bit of line with the reference guide which resulted in a non-straight line as shown on the right. After this first run I understood the machine better and did not repeat the same mistake. This is a very dangerous tool and I made sure I had the appropriate PPE on(safety glasses, apron) and made sure my hair was not near any rotating parts.



After making one pass I changed the guides so that it would cut the excess material on either side of the first cut. The final result as shown on the right was a groove in the material in which the other piece plywood would be glue into. On the first try I struggled to align the rotor bit with the edge of the line as you could not see because of the routers extraction system. After testing the size of the grove on the first cut with the other piece of plywood I found that it was slightly to big and would result on a weak sloppy joint. So I toke this plastic extraction system off so I could have a clear view on the router bit. This resulted in more dust but made it a lot easier to make accurate cuts and the second trial was a mush tighter fit.

After both pieces fit together well I used pva glue to mate the two and form a secure bond. After I had applied a thin cover of glue to both the groove and edge of the plywood I used clamps to hold the joint in place whilst the glue set.

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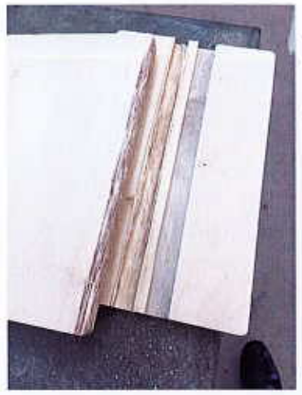
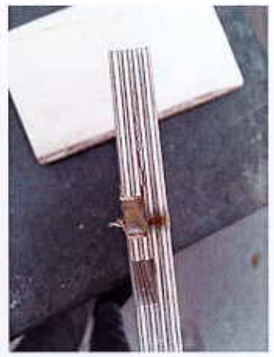
As shown above this joint has a simple a elegant aesthetic. This provides a nice clean alternative to the finger joint in terms of appearance.

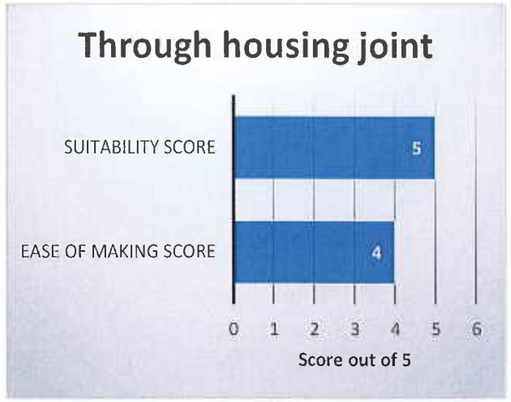
User comment: "this joint is nice simple to build, strong and aesthetically nice. I like how time efficient this is using the router compared to the finger joint."

The next test was the strength to destruction test which has been a constant between all of the joints. As this joint felt very sturdy in hand I decided to go straight to adding 9.7kg net weight hanging of it. As shown in the image no flex occurred when this weight has applied. After that I used a hammer in conjunction with the weights to apply enough force to break it. It took a couple solid hits with the hammer to make this joint break free.





The result of this break is above. As shown in the image the same issue occurred with the plywood as in the finger joint test. The plywood delaminated instead of the joint failing this further proves that PVA glue is stronger than the outer layer of plywood. However this joint require a substantial amount of force to break which is highlight with the stress fracture in the plywood shown in the right image. This joints strength is a desirable characteristic for the application of this joint in my project.



Butt joint:

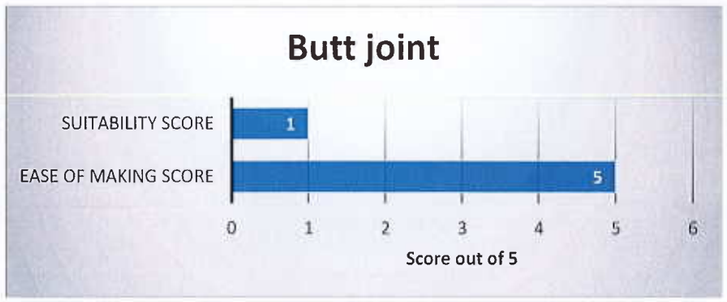
This joint is a very simple joint to make and I simply took two pieces of 12mm plywood with the same side length. Once cut the two pieces I applied a thin layer of PVA glue along on of the edges of the plywood. Making sure not to use too much as this would result in excess glue on the edge of the joint. This joint only took 10min to make highlighting its simplicity.

The next and final step is to securely hold the two pieces in place as the glue dries. This is done with a piece of wood on the inside to make sure it is square and help of too quick jar clamps which aid in the strength of the joint and hold it in place. Leave glue to set for 12 hrs before strength testing the joint to ensure that the PVA glue has fully set and that it produces it strongest bond.

The Butt joint has a plain and simple aesthetic which is evident of the time it took to manufacture. It does not share the elegant simplicity of the thru housing joint or the complexity of the finger joint which is why its ranked lowest in the appearance category.

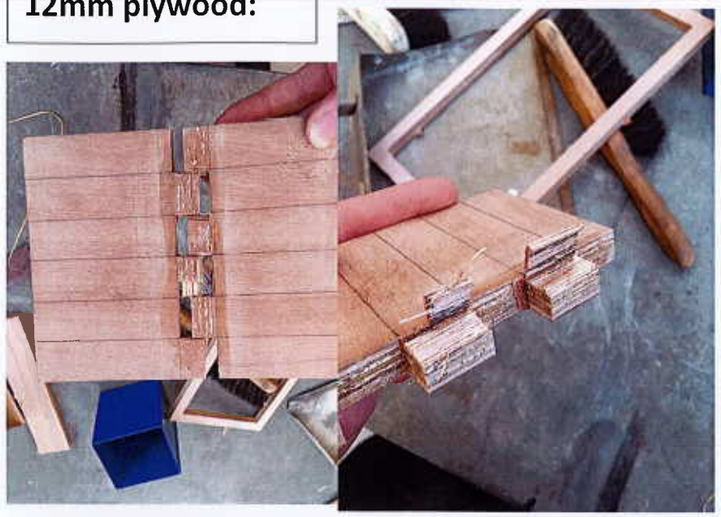
This joined failed spectacularly under the strength test with it breaking under just the force of the 9.7kg weights. This highlights how it basic construction hinders it in a strength test. It can be noted that this joint failed before the material and did not delaminate the plywood highlighting it weakness. This lack of structural integrity would not be suited for the specific application in my project and therefore rules this joint out.

User comment: "I am concerned with how easily this joint broke under force I don't think this will be well suited for the application in the project"



Material testing:

12mm plywood:



Whilst testing the finger joint I used 12mm plywood and found when I went to break the joint the joint didn't fail only the material. As shown in these picture here you can see how the plywood has stated to delaminate and the outside layers have broken off causing the joint to fail. This highlights the importance the grade of the plywood makes and the glue used. As the pva is stronger than the material it put emphasis on this failure. With the higher grade plywood the outside layers will be composed of higher quality wood.

When I was testing the 12mm birch plywood I made a small jig to measure impact resistance. This jig helped keep the drop height the same for each test and simply holds the steel rod used to impact the wood in the same place every trial. After multiple drops of this steel rod the material showed virtually no indentation from the impact. This is because this plywood has a hard and durable outside layer. The metal rod was dropped from a height of 12cm the fact that this material is very impact resistant is desirable as it will be position in a place that will be hit as it is in a tight space. This materials impact resistance adds to the materials durability and the overall durability of the product.

I constructed two flexibility and structural integrity test on this birch plywood the first being placing the material in between to pieces of metal tube and standing on it to test its lateral strength when supported on both sides. Whist undergoing this test I felt no flex when 70kg was standing on it. The second test involved hanging a group of weight with a net weight of 9.7kg while the other side was firmly clamped to a work bench. during this no flex in the material was seen. This primary testing supports my secondary research and further highlights the strength and durability of this material and how it complies with all of the constraints when choosing a viable material option.

As shown in the image above this material has a very appealing aesthetic with a warm/light coloured appearance and fine grade detail. It also has a very clean defined side edge with minimal air pockets which adds to its aesthetic appeal. When testing this material I used cuts of from the CNC router and I am impressed with how cleanly this material cut leaving no splinters or delamination. This is important I am going to use this machine to cut out my panels for my project. This adds to the materials benefits and justifies it as my chosen material.

Process testing CNC router:

The first step in this process is to draw up a design/shape on solid works which forms a CAD drawing which can be loaded onto the CNC machine through software. Once this is loaded on you need to position the piece of material square on the router bed this is done through the aid of the origin point on the bottom right hand side. When positioning the material make sure that the grain is going in the correct direction to achieve a smooth cut without splinters. After this it is time to turn on the air extraction system which claps the material down to the table to ensure that it does not move when the piece is being cut. After all of this is done press start and stand back to keep a safe distance from the router cutter. Pull boards across to contain the router bit. This is in case the route bit breaks and shoots off.

Some of the benefits of this process is

- Repeatability
- No human error
- No breaks are needed wit this kind of machine
- Consistent and accurate
- Less skilled people can operate cnc machines unlike manual laths/ milling machines
- Doesn't need as many workers which results in cheaper manufacturing costs.

Some of the disadvantages to this process are

- Expensive(capital investment)
- Fewer workers= less jobs

However due to this machine already being in the tech rooms and being a one off production it negates these negatives therefore making it an ideal process to use in production of the product.

After a finished cut you can see the clean accurate line that the cnc router has cut.

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Particle board:

I tested this material against the 12mm plywood with the same strength test to see how much this the particle board would deflect. Clearly from this image you can see how it is starting to bend down and given that this is 17mm particle board and it is still showing more flex than the 12mm plywood with the same 9.7kg weight hanging of it. This result is in line with my secondary research about this material. This lack in strength is not appealing for my project as it will need to carry and support heavy items such as a 20l water tank without showing signs of flex.

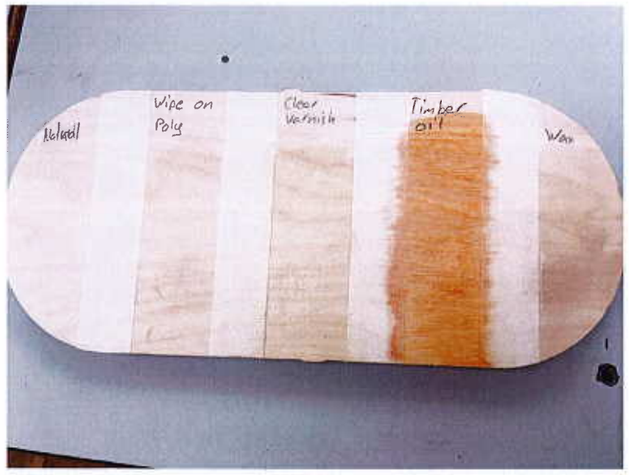
I placed a small piece of particle board and plywood in a bucket of water to test there moisture/ water resistants. I left them in this bucket for 12hrs and observed the changes. This is important as the cupboard will hold water and in case of a spillage of water getting on the cupboard the material must not easily rot and loss structure.

As shown in the image above you can see how much the colour of the particle board changed from being in the water. This shows that it has absorbed this water. When in hand this piece of timber felt heavy and weak and the corners when easily crumbled by hand. The plywood on the other hand felt and looked similar to when I put it in the water and wasn't subject to any change. This is in line with my secondary research on these materials and presents no surprises.

From a visual aspect this material is not appealing.it does not have a natural grain as it is made of mixed scrap timber glued together this produces a very inconsistent pattern. It colour has not depth and it does not have a side grain like plywood. This combined with its lack of strength makes it not desirable as a material option.

Finish testing:

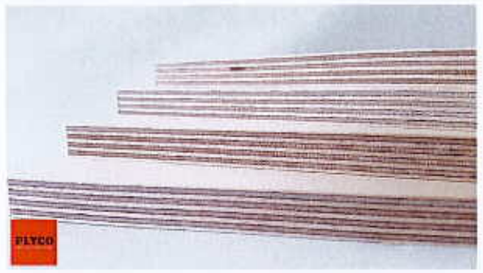
When testing finishes I used a range of natural and polyurethane products. Including poly wipe, wax, clear varnish and timber oil. All of these had different effects on the colour and finish of the material which is illustrated below.

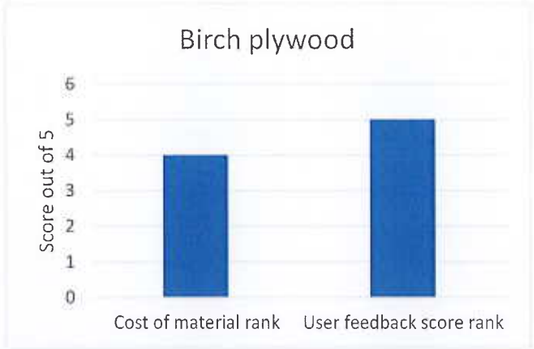


I set up this test on a piece of birch 12mm plywood and used masking tape to segregate the different finishes. On the far left I set a control with the natural finish of the wood to compare with the others. The poly, wax and clear varnish do not darker the wood by much however the timber oil makes it have a significantly darker appearance. From feel the varnish feels the strongest with an extra protective layer over the wood.

Final materials/joints/finishes:

12mm Birch premium plywood:



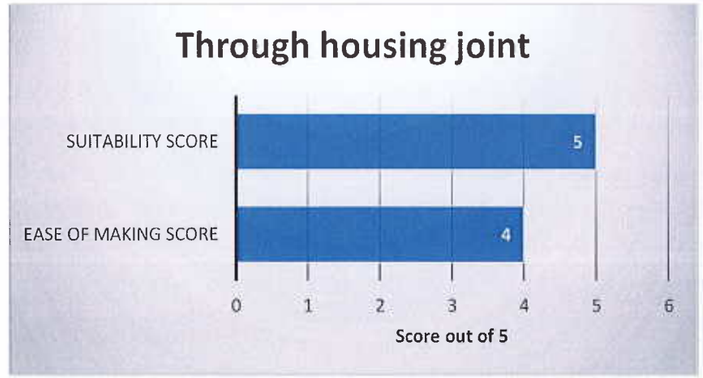


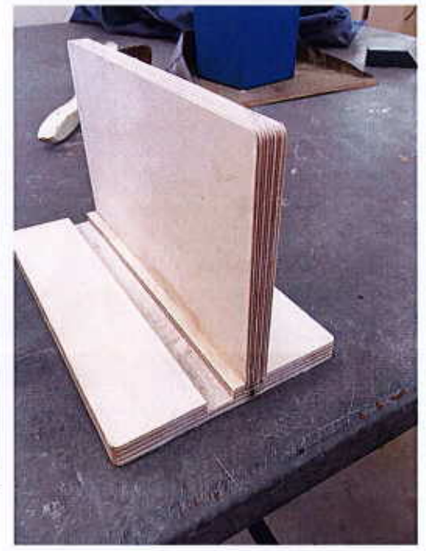
I have decided to use 12mm birch plywood as my primary material for the cupboard as it is the option out of the various materials that I tested and researched. This is because of its desirable properties which include being very strong for its weight, aesthetically pleasing, very accessible, and good durability. It strength to weight ratio is important as the product must be structurally sound as it will hold weight and act as a support for the fold out bed. It also must be light as the van does not have much power and added weight will reduce aspects of handling and fuel efficiency which are both important to my end user. The material must be durable as this product will see regular use and won't be used delicately. Another reason that plywood is my preferred material is the rest of the conversion is made out of plywood and making this side cupboard out of a different material will disturb the aesthetics of the fit out and won't look as clean. Through my primary research and secondary testing I have found that 12mm birch premium plywood has the best characteristic and ticks all of the boxes. From the graph above it supports this decision and highlights its high results in both categories.

Water based clear varnish:

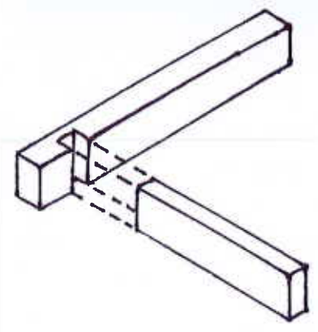
I have decide to use a water based clear varnish as my material finish. This is because it protects the wood and gives it desirable characteristics such as water resistant, more durable and gives it a slightly darker aesthetic which is good as the birch plywood is quiet light. Applying a finish to the material will add to the durability of this product and make it easier to take care of. Through my primary research and secondary testing I have come to the conclusion that this is the best finish to use for my application and ticks all the boxes with my end user. One area that was especially important to my end user was that it had no strong fumes after application. Some of the poly based varnishes can have a very strong smell for a while after application this is especially amplified in a small enclosed environment like the van and will make it unpleasant for my user. For these reasons I have chosen this finish.

Through housing joint:

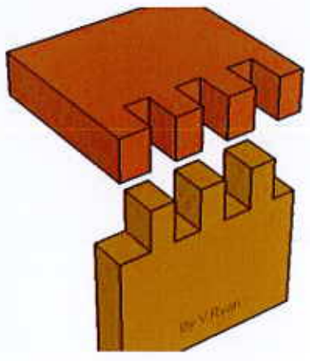


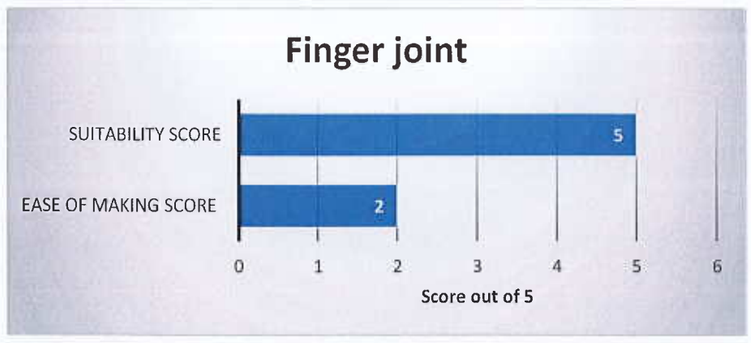


I have decided to use this joint for the inside cupboard levels. This is because this joint is a very strong sleek joint that will work perfectly in this situation. As shown from my secondary testing this joint rivals the strength of a finger joint however it is much easier and quicker to make user a hand held router. This joint needs to be strong as it will hold a lot of weight. This joint can also be cut out using the CNC router if I know exactly where it will sit. The graph above provides numerical data to support my decision on the joints that will be used in this product. It shows that this joint is both very suitable and easy to make which results in it being chosen as a final joint for the product.



Finger joint:





I have decided to use finger joints as one of my joining methods for this project. This is because when this joint is set it is very strong and has no flex under load. This means the cupboard will be able to hold weight easily and won't require a frame which will add weight. This strength will help to support the weight and make sure that the cupboard won't fall apart due to regular harsh use. This joint is very time-consuming however I am planning to cut this out using the CNC router which will make this process far quicker and more accurate. This joint is very aesthetically appealing when combined with plywood and you can see the side grain of the wood. The graph above provides numerical data to support my decision on the joints that will be used in this product. It shows that it is very suitable and due to the fact that it will be cut out using the CNC router it will make it very easy to produce which will negate this low score in this section.

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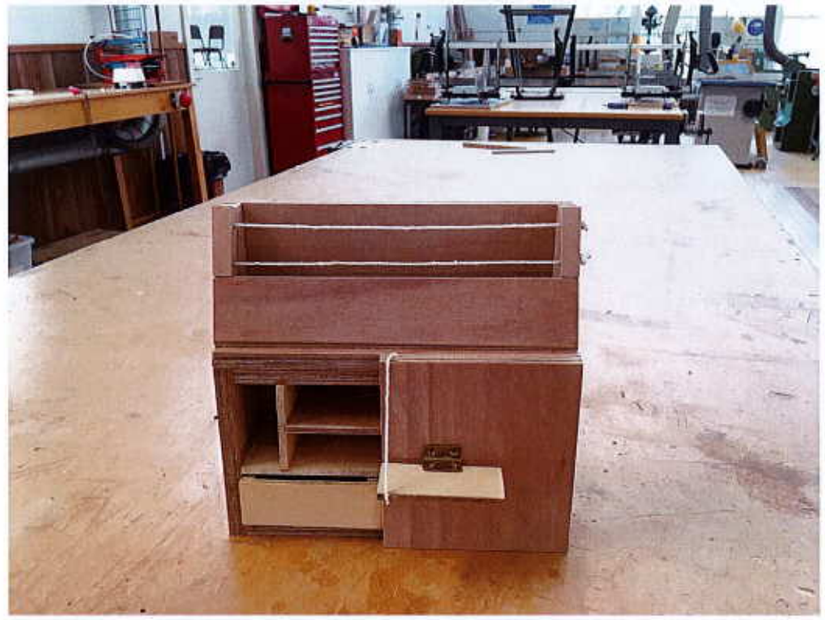
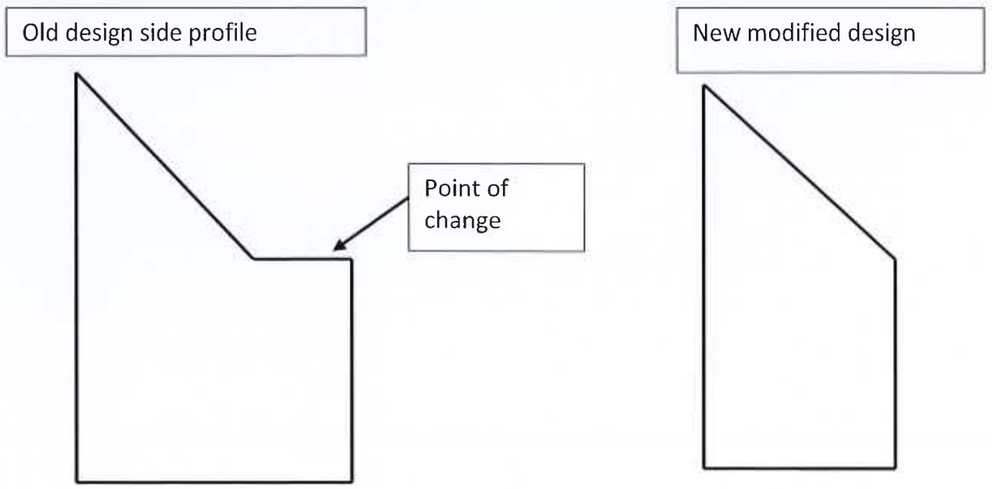
Model of design:



From creating this model I leant that the small table top that I put in my design option is pointless as this is a 1/5th scale model and as you can see from the picture it will be two small to actually be functional and will take up useful storage space. The modified design will have that angle continue until it crosses the vertical front of the cupboard. I will take this into consideration when producing the final product. Another thing that I learnt from producing this model was what possible joint I could use which helped me narrow in my research and testing of joints. This model showed how my design has a sleek and clean aesthetic. It also puts on emphasis on how much storage space this design will offer with the combination of the large pull out draw divided selves and top section. From this model it is easier to visualise how it will fit in the van and reaffirms a strong design. In this model I have not include a countered back edge however the final product will have a slightly cured rear profile to make it fight better in the van. The process of modelling/ prototyping is an important stage in product development especially when you are not decided on one design and have multiple models that you can compare against. The models also shows proof of idea, it is easy to see a design that doesn't work through the creation of a model.



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Criteria 5: Risk management:

Machines/ equipment	Stage of production	Areas of hazard	Possible injuries	Risk control	PPE
CNC router 	Cutting out main frame of design. This will be done using this machine as it is very time effect and with give me an accurate base which I can than modify to fit in my end users van.	- Router cutter - Exposed moving parts - Snapping router bit - Debris - Dust - Work slippage	- Being cut by the sharp router bit - Being hit by the router bit if it snaps in the wood. This would result in serious injury as it spins ant 9000rpm. - Injured from flying chunks of wood - Being hit by the piece of work it comes loose of the bed of the router	To minimise the possible hazards of this machine the user should ensure that they were all of the appropriate PPE which include safety glasses and a workshop apron. The user must ensure that the guard is secure and in place before turning on the machine as this minimise the debris and dust that can be kicked up by the router bit it also makes sure that the router bit cannot fly out if it snaps. Make sure that the are evacuation system is on to ensure that the sheet of wood is secure on the bed of the router and cannot move during the cut.	 
Hand held router 	Machining groove in the wood for the thru housing joints	- Exposed moving parts - Electrical hazard - Potential harm through entanglement - Projectiles	- Being cut by the spinning router bit causing deep cuts - Being entangled through loose clothing or long hair by the spinning router bit. - Striking, cuts - Electrocution - Eye damage from projectile	Ensure all hands and fingers are on the top of the machine and away from the blade to minimise the risk of being cut from the router bit. Avoid wearing loose clothing and tie up hair if it is dangling close to the tool to ensure that you cannot become entangled. Ensure that all of the appropriate PPE is wore which include eye protection and work shop apron. Ensure that cords are not in walkways and are away from blades and are safety qualified.	 

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Electric hand sander 	To ensure that the end product has a smooth finish before applying a clear varnish	- Dust inhalation - Sawdust on ground - Mover parts - Projectiles	- Eye damage from dust and projectiles from sander - A collection of sawdust on the ground can make the area slippery which could result in falling and injury such as brushing and concussion - Dust inhalation can result in reparatory problems and can lead to irritated eyes and throat. Dust inhalation can also lead some forms of throat and lung cancer. - Grazes can occur from skin contact with the sanding bit while not severe still an injury to be occur of when using machine.	Ensure that all hands and finger are clear of moving sanding pad. Wear breathing mask when using in enclosed environments in working outside there should be enough air flow for dust to be blown away. Or use an sanding machine with an extraction system built in. Ensure that correct PPE is used when operating this tool which include eye protection, dust mask and work shop apron. Make sure this work is conducted on a rough surface so that it does not become slippery when dust accumulates on it.	
Jigsaw 	Used to cut out the edge of the cupboard to make sure that it fits flush in its location in the van.	- Entanglement - Impact and cutting - Electricity - Slips/trips/falls - Dust	- Long hair, loose clothing, rags and jewellery can become entangled in the moving parts of the equipment. - The mobile exposed moving saw blade presents a significant risk to an operator's hands and body parts. Could result in severe cuts. - Damaged or frayed electrical cords could pose the risk of electrocution to the user.	Ensure hair, loose clothing, rags and jewellery is kept clear of moving parts when in use. Aprons can be used to restrict loose clothing. Hair ties/hair nets can be used to secure long hair. Ensure that appropriate PPE is worn which includes eye protection and workshop apron. Keep hands and body parts away from the moving blade and have a secure grip on the machine encase it grabs or moves suddenly.	

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Bench saw 	Resizing material to specific dimensions. Will be used be a qualified technician. (Ian)	- Entanglement - Impact and cutting(severe) - Noise - Electricity - Dust	- Severe cutting from spinning blade, possible loss of limbs - Breathing problems - Electrocution - Eye damage from flying debris	Ensure hair, loose clothing, rags and jewellery is kept clear of moving parts when in use. To avoid entanglement. Keep hands a d body parts clear of spinning bland and moving parts. Ensure that correct PPE is worn which includes eye protection, workshop apron and leather shoes to minimise risk of possible injury. This machine can only be used by a qualified teacher/technician, do not attempt to use this machine as a student.	
Tape measure 	Measuring out dimensions of materials.	- Cutting	- Cuts to hands(minor)	Ensure that the tape measure is wound in slowly to minimise risk of injury.	
MIG welder 	Welding the cradle for the water tank to sit in.	- Fumes and vapours - Lighting(arc) eye damage - Electricity - Heat and burns - Radiation - Exposure to fire	- This process causes the release of toxic fumes and vapours which can be harmful for the users health. - The arc that the welder creates with the material is a very bright light which can cause arc eye if no PPE is worn when welding this can result in severe eye damage. - Burns can occur from touching hot pieces of metal after welding. - This burns can also be on arms if the user has exposed skin from the bright light, heat and radiation.	To ensure that the fumes created from the welding do not impact the user the workshop space must have a sufficient extraction system which must be turned on before use of welder. The user must wear correct PPE to ensure that they are not exposed to the UV and IR radiation. This includes welding mask, long overalls, leather frame resistant apron and thick welding gloves. This will minimise the risk to eye damage radiation exposure and burns.	  

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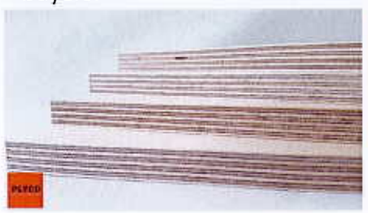
			- The user can be exposed to IR and UV radiation which results in severe burning and discomfort to unprotected skin as well as skin cancer.		

Production of this product in industry:

For this product to be made in mass industry it would require to following changes. Currently I am using a manually loaded CNC router however to make this process more efficient I would change this to a fully automated CNC machine(image to the left). This would make the process a CIM production line. The use of the CNC machine means that it is very efficient and will easily and accurately repeat the same process over and over again with-out breaks. This makes time and cost efficient to produce this product on a mass scale. This is where economies of scale come into effect as the more units produced the cost per unit will decrease.

A fully automated machine like this would be used in conjunction with the CNC router so it does not need to be manually loaded. This will form a far more efficient

The material used would not change either as it comes in industry standard sizes and is easily accessible to producers. It is also very easy to use in conjunction with the CNC router. However you would include the option for the customer to choose between a low and high grade plywood(image below). The low grade plywood would give the product its structure however it would not have as nice aesthetic so you would use a plywood with a birch veneer to give it that high quality look whilst keeping cost low. This finish would already be on the wood with a clear varnish over the top to ensure it protection and durability, having this finishing process already on the wood before cutting it out will reduce cost and time. The high grade plywood option would be finished with the same pre-production clear varnish as the low-grade. No veneer would be used on this material as it already has a nice aesthetic. By making it out of two materials it opens up the possible market as you can offer the product at two different price points which will appeal to more buyers.



An example of the two material. High grade plywood on the left and low grade plywood with a veneer on the right.

One aspect that would be challenging to produce on mass is the customization into each individuals van as each have slightly different sizes and dimensions for the space. One way to combat this would be to specify your business in the creation of fit outs for a small number of the most popular van makes and types to fit out. This data can be collected from surveys and market research. By specifying in only a few models of van you could design a custom fit cupboard for each of these and have so what the CNC router cuts out fits exactly into place without any further modification this would require a change in design to make it fit perfectly in these specific models. This would limit your market however, it would be far more time efficient and repeatable than one off custom fit outs. You could also sell these units in flat pack form which would then increase market to overseas and customers who want to put it together themselves. This would be possible as the cut outs from the CNC router would be constructed using Knock down fittings require the customer to simply bolt/screw the cupboard together. This would increase your possible market further as you could offer these flat pack solutions at lower prices. For these reasons it would be reasonably easy to commercialise this product and turn it from a one off product to a mass scale production item.

Fully automated CNC router

An example of flat pack furniture.

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