ENGINEERING REPORT

‘Better Living in the Humanitarian Village’

Shelter + Project

CLASS

COMMUNITY LEARNING AND SOCIAL SYSTEM

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Executive Summary

The content of this report discusses the stages that directed and influenced the design from several engineering aspects. As C.L.A.S.S is a system that contains products that contribute to creating a learning environment which promotes social connectivity for youth living in humanitarian villages, the parts and subassemblies needed to be designed in a cost effective way that is viable for mass production and distribution on a global scale. The major elements of C.L.A.S.S. that have been designed for this group project are the Prep Pack, Make-it-Module and the Class Cube. These three fundamental elements of the overall system, and their subassemblies or major parts have been analysed and discussed for coherent engineering rigor and design justification. The materials selected, the manufacturing processes and sequences and detailed methods of assembly have been outlined for major componentry. Several rough calculations were conducted to direct the design of some major products during the initial stages of the project with some evident in this report. The important load bearing components were studied with Finite Element Analysis (FEA), where the results obtained were used to justify the designs and make changes appropriately.

The major products and the entire system was then analysed to discuss economic viability of C.L.A.S.S. by using rational cost projection. Strengths, weaknesses and design improvements have then been outlines and proposed to complement the reflection of the final outcome as a design solution for the problems and issues with supplies for youth living in humanitarian villages.

1. Introduction

C.L.A.S.S. addresses the requirements needed for a classroom environment. Our project direction was focused on the Pacific/Indian Ocean region and South/East Asia where there are less developed countries and a high risk of Natural catastrophes. C.L.A.S.S. provides a compact solution to building a temporary school by providing furniture facilities to a class of one teacher and 30 students. The C.L.A.S.S. unit fits easily on a pallet, making it easy to transport and compact enough to get to harder to reach places.

The Prep Pack gives each child something to hold their belongings as well as being the child's individual seat in the classroom or home. The Make-It-Modules (MiMs) promote social interaction through the two students per desk arrangement as well as providing play equipment in an educational manner. The C.L.A.S.S. Cube provides a durable housing for the entire system as well as doubling as the teacher's desk and storage to pack away stationary and the Make-It-Modules. Each product was developed for durability as well as ease of manufacture. Over the course of development, many changes were made to each of the products to optimize its usability and function.

In this report the materials and manufacturing processes of all componentry and subassemblies have been selected to ensure that the overall product is cost effective and sustainable. The overall C.L.A.S.S unit will be mass-produced and stored in several strategic locations around the globe, so when disaster strikes the product can be distributed efficiently. The manufacturing processes, the sequence of processes and the assembly details of all major sub-products and their subassemblies have been discussed in this report. Finite element analysis (FEA) and other calculations conducted are also show to justify the design on load bearing componentry. A full projected cost analysis of each major sub-products and the overall system has been projected and compared to other similar products and systems in the market to demonstrate economic viability.

2. Material Selection

2.1 Prep Pack

2.1.1 Rigid Panel (GD.SP-C.PP.1)
The Rigid Panel is largest component, and is made from HPDE due to its mechanical properties such as high toughness and rigidity, as well as its availability and ease for injection moulding. As this part is subject to loading it is important that minimal deflection and wear occurs. There are running tracks integrated with the flat platform, which need to maintain shape for long periods of time, as due to the HDPE properties this product part can withstand use without deformation occurring.

2.1.2 Leg Beam (GD.SP-C.PP.2)
The Leg Beams are made from standard extruded lengths of 6106 Aluminium Alloy RHS with Round Corners. This material is readily available and easy to source, as it is a standard extruded section. It has a high strength to weight ratio for an aluminium alloy, which is ideal for this application where minimal weight is desired while the material is still strong enough to support the weight or a large child (55kg).

2.1.3 Leg Plug (GD.SP-C.PP.2.5) and Rubber Boot (GD.SP-C.PP.3)
Both the Leg Plug and Rubber Boot are moulded from EPDM Rubber, as it is readily available, has good flexural strength and durability while providing grip.

2.1.4 Textile Subassembly
All textile componentry is made from non-rip Cordura Nylon fabric, which is most commonly used in the market for back packs and camping equipment. It is lightweight, flexible, strong and durable. The padded sheet that is sewed the nylon fabric is made from close-celled polyurethane foam which is water repellent and still soft enough for comfort when sitting or carrying the Prep Pack on your back.

2.1.5 Fasteners and Bushes
Most fasteners are standard Nylon OEM parts, and the sliding washers are standard PTFE parts due to the self-lubricating properties and low coefficient of frication. The Bushes are made from Nylon 606 for rigidity and toughness properties.

2.2 Make-It-Module

2.2.1 Panels (A, B, C, D1, D2)
All rigid panels in the in the Make-It-Module are made from Deluxe Vinyl PVC due to its high strength-to weight ratio and impact resistance which is needed for modular object that are designed for children to play with. It is also important for the modules to be light. The twin wall foam PVC has a much lower density than other plastics whilst being structurally sound.

2.2.2 Rubber Strips (R1, R2)

Both Rubber Strips are made from OEM extruded Polyurethane rubber strips to provide flexibility to replicate live hinges.

2.2.3 Textile Exterior

The textile exterior is made from a Polyester version of the 3M Hook and Loop Material. It is suitable for outdoor conditions and has improved water resistance compared to other Hook and Loop Materials. It is flexible, strong and durable.

2.2.4 Sewing Thread

An OEM heavy duty Nylon thread will be used to sew the pattern of the textile exterior. Since the thread would be the first part to deteriorate after being exposed to a lot of tension from the Velcro constantly being pulled apart.

2.3 Class Cube

2.3.1 Main Sheet (GD.SP-C.CC.5)

The Main Sheet is made from thin walled HDPE Sheet with a gloss finish. At this part is n the exterior and will be subject to impact during transportation and shipping it has been made from HDPE due to toughness properties and impact resistance.

2.3.2 Back Panel (GD.SP-C.CC.HF.3) and Door Panel (GD.SP-C.CC.HF.4)

Similar to the Main Sheet, these are also made from HDPE with a gloss finish, as they required the same properties. Along with reducing any sorting steps required when recycling.

2.3.3 Housing Frame (GD.SP-C.CC.HF.1)

The Housing Frame is made from Aluminium Alloy 360T that is corrosion resistant and strong to protect all the internals and support heavy loads for stacking the entire system on top of each other for transporting.

3. Manufacturing Processes and Sequences

3.1 Prep Pack

3.1.1 Rigid Panel (GD.SP-C.PP.1)

The Rigid Panel is manufactured by injection moulding HDPE. The component requires a basic mould design with two sliding cores to create voids to be used as running tracks. The gate location for injection moulding would be on the centre and the parting line would be along the flat face of the Rigid Panel. It has been designed to hide the Gateway and parting line as the Textile subassembly wraps around this part. Fillets and draft have been applied and due to the simplistic form of the part undercuts are not present. The only problem that could result is shrinkage along the flat face, due to the rib pattern on the flipside, however if this occurs it will also be hidden by the Textile componentry. The Rigid Panel requires no coating or finishing, as the colour is predetermined and the produced part will be ready for assembly.

3.1.2 Leg Beam (GD.SP-C.PP.2)

The Leg Beams are standard RHS extruded Aluminium but do require post machining to suit the design. Each Leg then needs to be drilled and milled to create the running track and pivot holes. The cut edges must then be deburred to ensure that swarf or sharp barbs do not come into contact with the users, as well as other componentry to avoid damage.

3.1.3 Textile Subassembly

The textile parts are prefabricated and cut to then come together to create a bag subassembly. The Padding is made from expanded closed-cell polyurethane foam which is heat sliced into shape.

3.2 Make-It-Module

3.2.1 Panels (A, B, C, D1, D2)

All rigid panels made from Deluxe Vinyl PVC are extruded to standard lengths. The Panels are then Laser Cut to meet the dimensional requirements and no further processing is required. The edges are then chamfered to reduce the likelihood of cutting the fabric that will encase it.

3.2.2 Rubber Strips (R1, R2)

Both Rubber Strips made from OEM Polyurethane rubber that is extruded and then cut to length.

3.2.3 Hook and Loop Strips (GD.SP-C.MIM.Ext)

The exterior is made polyester 3M Hook and Loop Fastening Material that is sourced by the Rolls, and then cut to size to suit the textile pattern.

3.3 Class Cube

3.3.1 Main Sheet (GD.SP-C.CC.5)

The Main Sheet made from HDPE will be sourced as extruded sheets from suppliers. Laser cutting the flat sheet that will then be thermoformed to create the bends will make the rivet holes. Extruding the U-shape was considered, but due to the large scale and the impractical size of die moulds for extrusion, it was decided that it is more practical and cost effective to thermoform large HDPE Sheets. Once formed, they will then be ready for attaching to the housing frame.

3.3.2 Housing Frame (GD.SP-C.CC.HF.1)

There are two main components to the Housing Frame, both are made from standard RHS extruded lengths with cross members to provide support. The top sections contain three beams that are cut to length and bent (using Mandrel Bending), to which the cross member are welded to. The bends allow for greater loading along with saving time and labour costs. The bottom frame is welded together using cut beams. These two sections are then welded together and the entire frame is then anodised to seal the surfaces and mask discolouration from heat affected zones at welded joints.

4. Assembly details

4.1 Prep Pack

4.1.1 Leg Subassembly

The Leg beams are for assembly once they have been cut and deburred. The rubber plug is inserted into the curved end of the Leg beam, and the Rubber Foot is squeeze onto the ground end of the Leg Beam to complete the Leg Subassembly. There are four leg subassemblies used for each Prep Pack, thus they are grouped in fours with the required quantities of bushes and fasteners for two sets of scissor Legs.

4.1.2 Stool Structure Subassembly

The Rigid Panel will need to be orientated with the flat face pointing downwards so the legs can be assembled. The PTFE Washers are placed between each bush and leg to reduce friction, then a running pin is inserted through the hole in the leg, the bushing/washers and the running track of the rigid panel to mate with another sliding washer and nyloc nut on the internal side of the Rigid Panel's running track. This is done for each of the four legs to constrain them with the Rigid Panel, where the outer legs are spaced with a larger running bush than the inner legs. The Legs one each side are then constrained to each other by inserting a running pin through running slot machined out the extruded legs, which allow the legs on each side to open and close independently with scissor motion. The Stool Structure Subassembly is complete once the all pins have been checked that they can run along tracks with minimal drag, as the nyloc nuts should not be tightening to nipping/jam point.

4.1.3 Textile Subassembly

The textile parts are prefabricated and cut to then come together to create a bag subassembly. All stitching uses Nylon thread with 10 tpi (threads per inch).
Initially the foam padding is slipped into a pocket with one open end that is then stitched. Then large and small pouches are attached (preassembled with zipper and zipper coil sewn on). Then the back pack straps, the handle strap, and the buckle straps are sewn into place to complete the textile subassembly which is later wrapped around the Rigid Panel and sewn along an edge to lock it in place. There are small flaps on each end that will be used to attach to each other once the Textile Subassembly is wrapped around and the flaps meet.

4.1.4 Final Assembly

The Stool Structure Subassembly is the foundation of the product, as the Textile Subassembly wraps around the length of the Rigid Panel (parallel with running tracks), where the two fabric flaps are to be pulled tightly and double stitched to constrain the two subassemblies together to complete the final assembly. Both sets of independent scissor legs should then be closed and constrained with by the bag buckle, with the rest of the textile pouches compressing and folding between the Rigid Panel Runners, the Prep Pack is ready for flat pack transportation.

4.2 Make-It-Module

4.2.1 Constraining PVC Panels within Textile Pattern
Each of the five rigid PVC Panels are inserted into their respective pockets in the Textile Pattern. The open ends of the pockets are then sewn together with heaving duty Nylon threading to effectively encase the panels with a child friendly, durable exterior.

4.2.2 Adhering Rubber Strips
The Rubber Strips are then adhered along the vertices that come into contact with the ground to provide grip and stability. The Rubber strips use a flexible acrylated urethane adhesive to adhere with the textile. It is essential that the adhesive is flexible to be compatible with the flexible hinges. Once the adhesive is set, the assembly is complete and the Make It Module is ready to be folded and packed for delivery.

4.3 Class Cube

4.3.1 Base Structure Subassembly
The housing frame (GD.SP-C.CC.HF.1) serves as the foundation that all other parts are built on or attached to. The Castor wheels are fastened to the bottom members of the frame. The base plate is then placed on top of the bottom frame members from the inside. The notches cut out from the base plate fit between vertical frame members, which constrain the plate in any horizontal directions. Hinges (Type A) are fastened to the front right vertical frame member in the centre to complete the Base Structure Subassembly.

4.3.2 Housing Door Subassembly
The Housing Door Panel is fastened on to the doorframe. Then hinges (Type B) are fastened to the right vertical member of the doorframe to complete the subassembly.

4.3.3 Final Assembly
The Main Panel is lowered on to the Base Structure Subassembly and fastened into place with mating curvature at the top surface – Main Panel covers the top and both sidewalls. The Panel is then fastened into place on the rear of the Housing Frame. The Door Subassembly is then installed onto the front of the Base Structure Subassembly where both Hinges (Type A and Type B) mate to create a pivoting door. The Class Cube is fully assembled and ready to house all other sub product and accessories.

4.4 Modules and Equipment

4.4.1 Prep Pack Module

The Prep Pack Module is an Aluminium frame with nylon fabric wrapped around to form a lightweight container to store the Prep Packs during the transportation stage. Handles are fastened to the top members of the frame. Fifteen Prep Pack are compressed and placed in the Module for transportation. (There are two Prep Pack Modules received with each C.L.A.S.S unit).

4.4.2 MiM Module

The MiM Module is also an Aluminium frame with nylon fabric wrapped around to form a lightweight container to store Make-it-Modules during the transportation stage. Handles are fastened to the top members of the frame. Thirty flat packed Make-it-Modules and placed in the MiM Module for transportation. (There is one MiM Module received with each C.L.A.S.S unit).

4.4.3 Equipment Boxes

Small pencil cases are prepacked with a specified amount of essential stationery. Also accessory packs containing glitter, stickers and colour blocks are included for children to customise their Make-it-Modules and Prep Packs. All of the OEM Pencil Cases and Accessory Bags are packed into the Card Board Equipment Boxes, which are stored in the housing. (There are two Equipment Boxes received with each C.L.A.S.S unit).

4.5 C.L.A.S.S

4.4.1 Fully Assembled

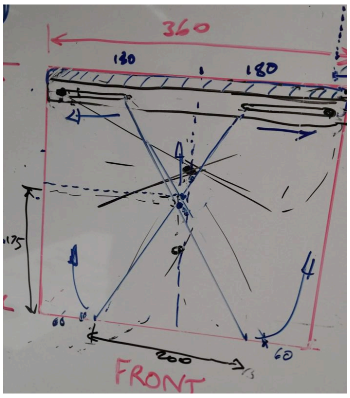
The C.L.A.S.S unit is fully assembled when it contains all items that have been deemed necessary and designed to address the needs of children in a learning environment, and be suitable for up to 2 years of use. The system includes:

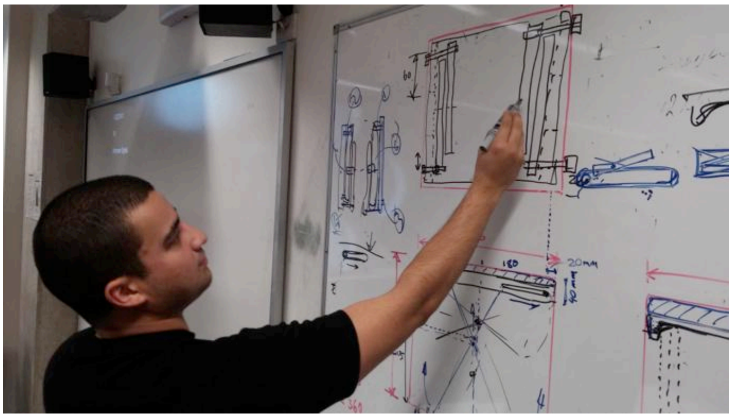
- 2 x Prep Pack Modules (30 Stools/Bags) (1 per child)
- 1 x MiM Module (15 desks/playground structures) (2 per child)
- 2 x Equipment Boxes (Stationery/accessories)
- 1 x White board (for Teacher/class)
- 1 x Large Stool (for Teacher)
- 1 x Housing (Teachers Desk/Container)

5. Calculations and Finite Element Analysis (FEA)

5.1 Prep Pack

5.1.1 Hand Calculations to determine important Part Dimensions



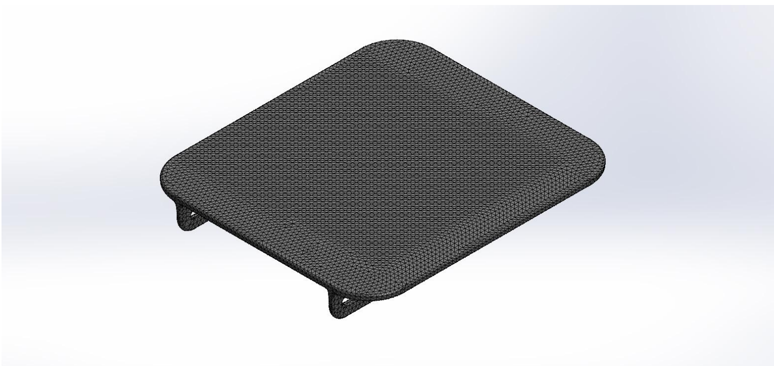


Working within parameters derived from anthropometric data, the overall sitting height, width and depth determined the size of the stool for ergonomic use. With the overall dimensions of the main components defined (GD.SP-C.PP.1 Rigid Panel) and the desired width and depth was locked in, and the dimensions of the legs and running tracks needed to be calculated and designed to fit within the parameters of the Rigid Panel – to deduce as desired height for the Prep Pack when in stool mode.

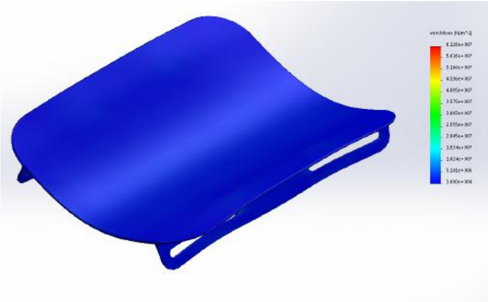
It was calculated that when the legs travel along running tracks (100mm long) a footprint of 200mm x 320mm would be achieved and adequate.

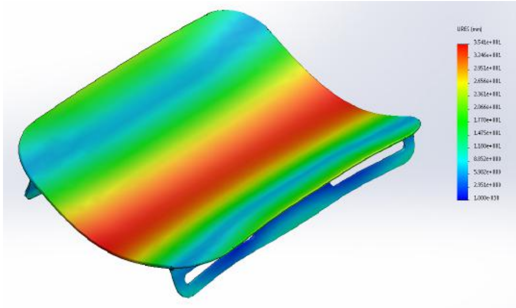
5.1.2 FEA of Rigid Panel (GD.SP-C.PP.1)

Finite Element Analyses were conducted on the Rigid Panel is it is a crucial part that is subject to loading when being used as a stool. FEA was used to investigate and clarify appropriateness of wall thicknesses as well as material selection. In all following scenarios the part was constrained with a four fixture surfaces located on the running track notches. A high quality mesh with fine settings was used for all FEA static studies conducted.



5.1.2.1 Rigid Panel : Wall thickness - 3mm

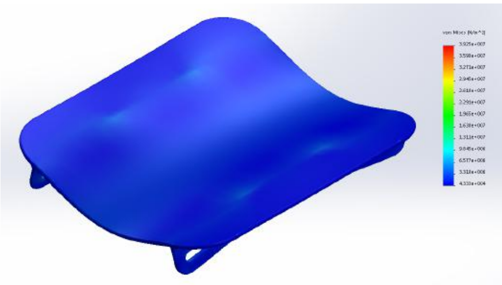


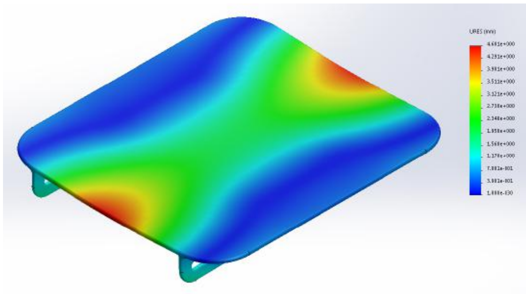


Max Stress = 6.13e+007 N/m^2

Max Displacement = 35.41mm

5.1.2.2 Rigid Panel : Wall thickness - 5mm

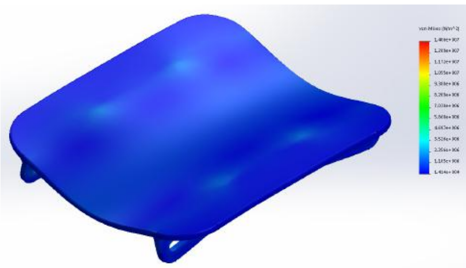


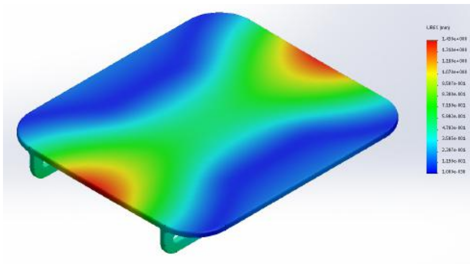


Max Stress = 3.92e+007 N/m^2

Max Displacement = 4.68 mm

5.1.2.3 Rigid Panel : Wall thickness - 8mm



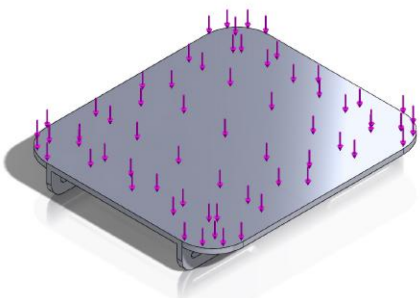
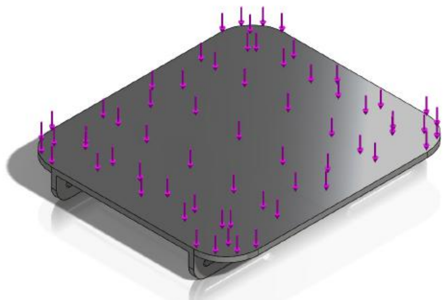
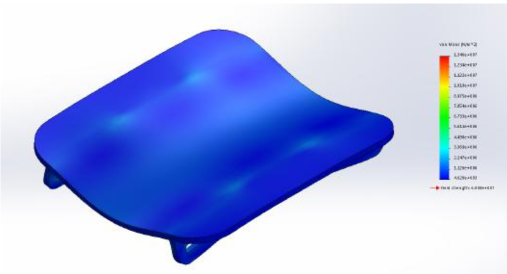
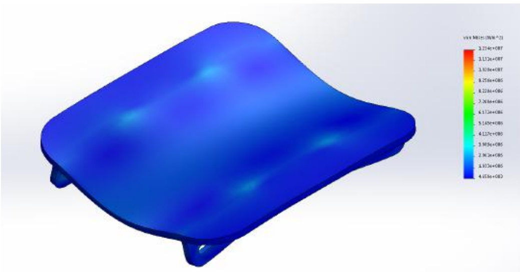
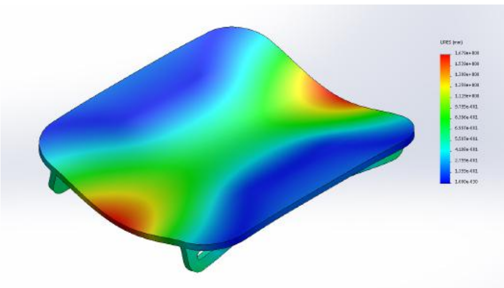
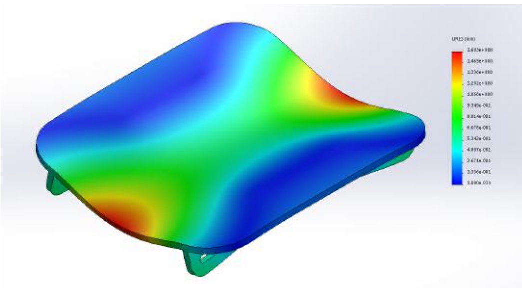


Max Stress = 1.41e+007 N/m^2

Max Displacement = 1.44 mm

The lower thicknesses were tested to reduce mass to effective minimize on weight and cost. However wall thicknesses of 3mm and 5mmm were leading to excessive deflection and 8mm thickness was decided to be appropriate for this application.

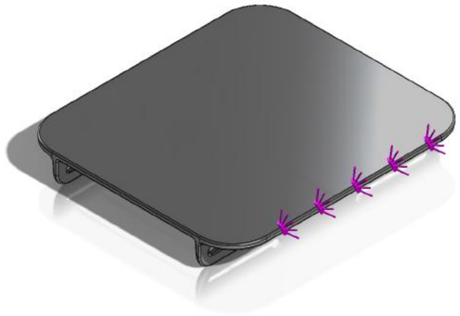
5.1.2.4 Rigid Panel : Material Comparative Study

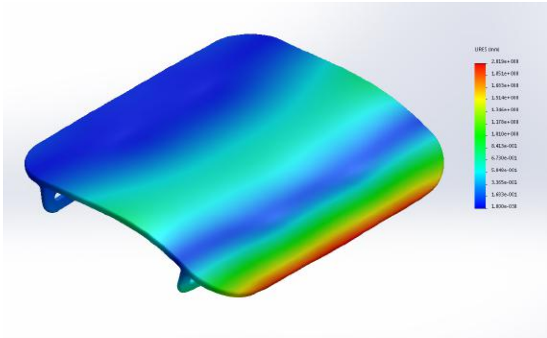
NYLON 101 (8mm wall thickness)	HPDE (8mm wall thickness)
Mass = 1.28908 kg  Distributed Load = 600N	Mass = 1.06714 kg  Distributed Load = 600N
 Max Stress = 1.34607e+007 N/m^2	 Max Stress = 1.23403e+007 N/m^2
 Max Displacement = 1.67923 mm	 Max Displacement = 1.60273 mm

From this comparative study HDPE was found to weigh less and result in less deflection when loads are applied. Thus it was confirmed that it would be an ideal material to be used for this injection-moulded part.

5.1.2.5 Rigid Panel : Long Edge loading

Testing to see the deflection that would occur when a child sits on the edge that will encourage the Stool to tilt.



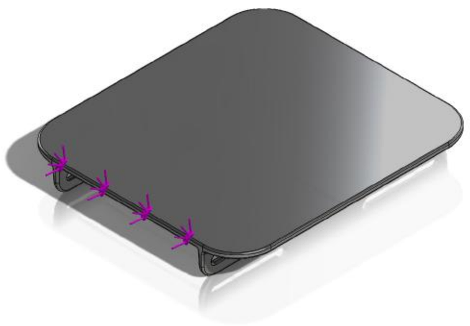


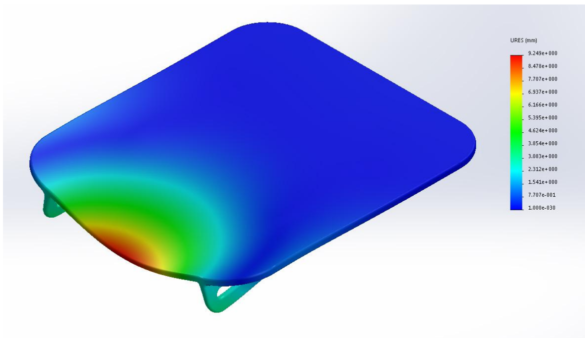
Load applied to edge = 600N

Max Displacement = 2.01902 mm

As shown in the exaggerated deflection image shows that the major displacement occurs along the edge without having a major effect on the running track. It is most likely that the stool will tilt and fall over before deforming the running track, which is ideal for the products lifespan.

5.1.2.6 Rigid Panel : Short Edge loading





Load applied to edge = 600N

Max Displacement = 9.24897 mm

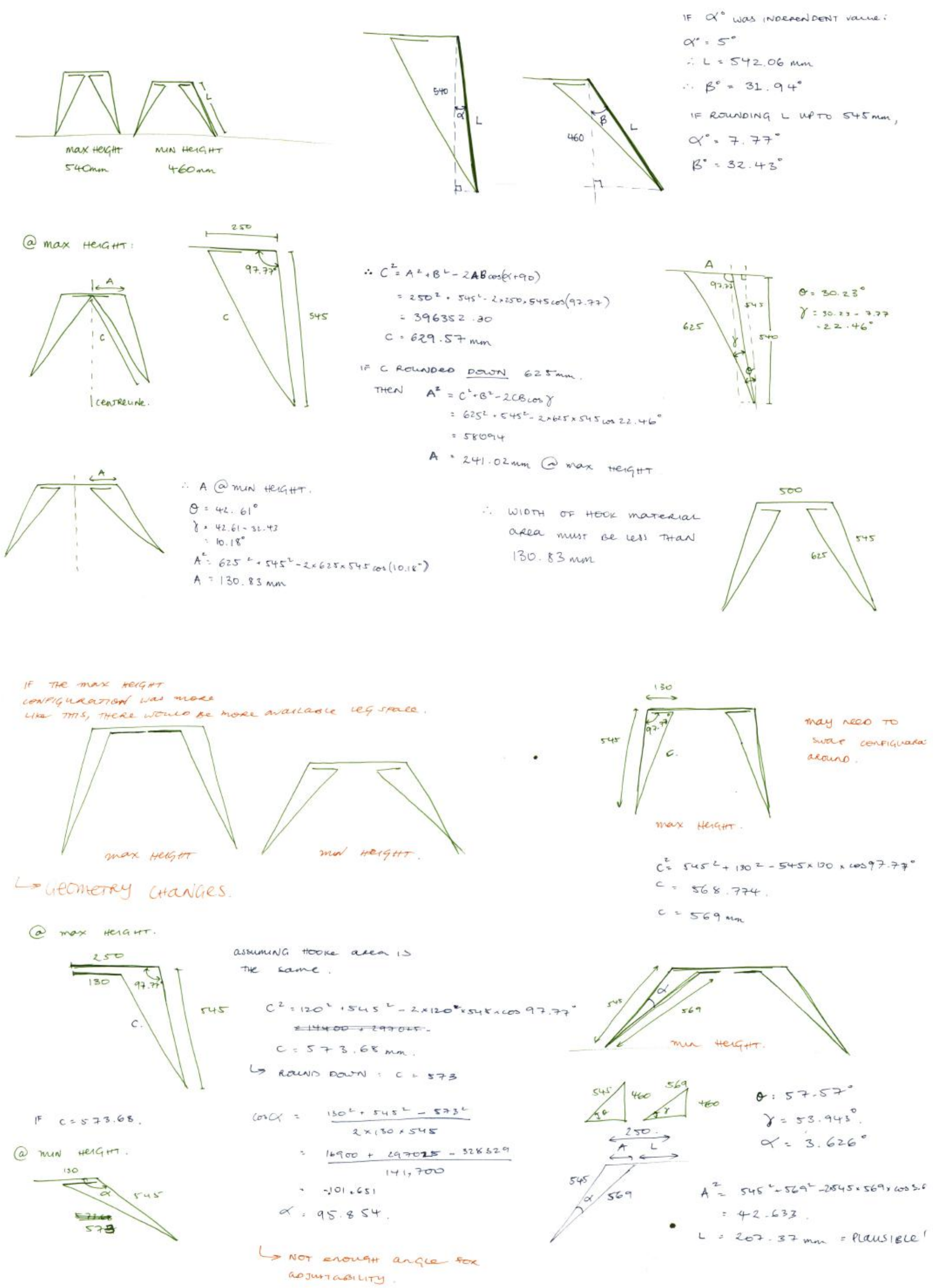
Similarly as the seen in the pervious section, the exaggerated deflection image shows that the major displacement occurs along the edge without having a major effect on the running track. It is most likely that the stool will tilt and fall over before deforming the running track, which is ideal for the products lifespan.

5.2 Make-It-Module

5.2.1 Hand Calculations

5.2.1.1 Geometry

The dimensions of the panels for the Make-It-Module was largely determined by the Geometry required adjusting the table from the lowest desk height of 460mm to the tallest desk height of 540mm.



5.2.1.2 Structural Analysis of Hook and Loop Tape

Available area from geometry is a bit under the requirement to support a 55kg child. However, the module can support the weight of a 52kg child.

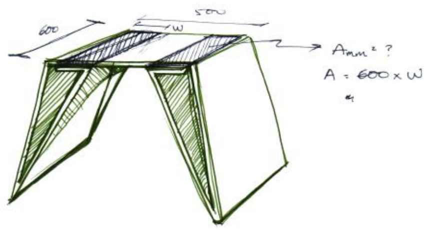
3M™ HOOK & LOOP FASTENERS.

SJ 3403 LOOP + SJ 3404 HOOK.

TENSILE (STATIC 1"x1"): 76g/cm²
72°F : 10,000mins (NO failure) (22.2°C)
100°F/100%RH : 10,000 mins (No failure) (37.78°C)

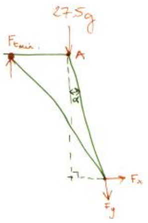
SHEAR (STATIC) : 155 g/cm²
72°F : 10,000 mins (No failure)
100°F/100%RH : 10,000 mins (No failure)

CLEAVAGE PEEL STRENGTH (RIGID TO RIGID) : 9 pounds/inch width.
160.72g/mm



EDUCATION.VIC.GOV.AU.
98th PERCENTILE 10 YEAR OLD BOYS: 55 kg.
98th PERCENTILE 10 YEAR OLD GIRLS: 50kg.

- TAKING 55kg as max LOAD.
- WORSE case scenario: CHILD SITS ON TABLE.



Where : $F_{t_{min}}$ = minimum Tensile force to counteract moment about A. from Leg sliding.

max STRESS @ min TABLE HEIGHT.
$\alpha = 32.43°$

$\therefore F_x = 27.5g \times \tan 32.43$
$= 171.4 \text{ N}$

$\therefore M_A = 171.4 \times 0.460$
$= 78.85 \text{ Nm}$

$\therefore F_{t_{min}} = \dfrac{78.85}{0.13083}$
$= 602.65 \text{ N}$

IF STATIC TENSILE FORCE OF HOOK & LOOP 76g/cm²
↳ 0.746 N/c

A cm² REQUIRED
= 808.32 cm

CURRENT POSSIBLE FASTENING AREA
130.83 x 600mm
= 785 cm².

$\Rightarrow F_t = 780 \times 0.746$
$= 581.54 \text{ N}.$

$\therefore M_A = F_t \times 0.130$
$= 75.60 \text{ Nm}$

$\therefore F_x = \dfrac{M_A}{\cancel{\tan 32.43}} \div 0.460$

$= 164.35 \text{ N}$

$\therefore \dfrac{Mg}{2} = \dfrac{F_x}{\tan 32.43}$

$= 258.67$

$M = 26.37 \times 2$
$= 52.74 \text{ kg}.$

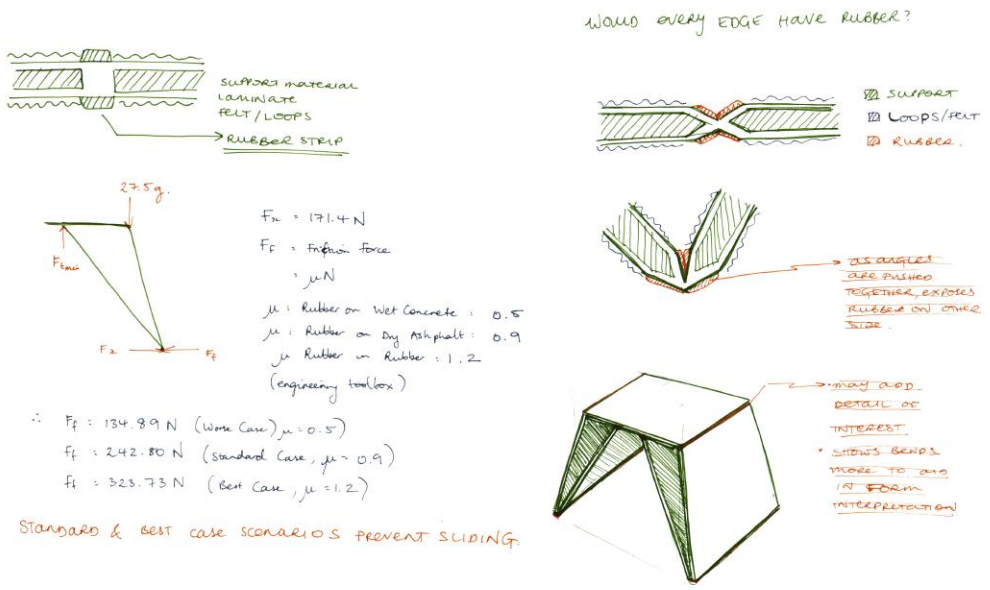
THEREFORE FOR CURRENT AVAILABLE area :

$130 \times 600\text{mm} = 78000 \text{ mm}^2$
$= 780 \text{ cm}^2.$

STATIC TENSILE FORCE OF 3M HOOK & LOOP $76g/cm^2 = 0.746 \text{ N/cm}^2$

5.2.1.3 Slipping Legs Scenario

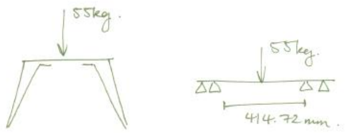
It was decided to insert Rubber lengths along leg/floor contact edges to stop slipping by providing some grip and stability.



The rubber strips will stop the legs slipping in moderate and best case scenarios. However, it may fail if floor is wet and smooth. From our research, the MIM would most likely be used indoors since this is where most temporary schools are set up.

5.2.1.4 Material Calculations

Originally the panels were going to be injection moulded HDPE, and respective calculation from that stage are shown below.



$\sigma_{max} = \frac{yFL}{4I}$, $y = \frac{\text{thickness}}{2}$, $I = \frac{1}{12}bh^3$.

$= \frac{1}{12}\, 0.6 \times h^3$

$= \frac{hFL}{8I}$

$= \dfrac{h \times 55 \times 9.8 \times 0.41472}{\frac{8 \times 0.6 \times h^3}{12}}$

$= \dfrac{12 \times 55 \times 9.8 \times 0.41472}{8 \times 0.6 h^2}$

$= 558.84 h^{-2}$

⇒ Lyondell Basell Lupolen (MatWeb Material Data)
6031 M HDPE - Injection Moulded Grade
Tensile Yield : 31 MPa. Tensile Modulus 1.5GPa.
Density. 0.963 g/cc.

$\sigma_{allow} = \frac{\text{Tensile Yield}}{3}$ (Factor of Safety of 3)

$= 10.3$ MPa.

$\sigma_{allow} = 558.84 h^{-2} = 10.3$ MPa

$h^2 = \dfrac{558.84}{10.3 \times 10^6}$

$h = 0.00737$ m

$= 7.37$ mm

$\Rightarrow I = \dfrac{bh^3}{12}$

$= \dfrac{600 \times 7.37^3}{12}$

$= 20015.78\ mm^4$.

$\delta_{max} = \dfrac{-PL^3}{48EI}$, $E = 1.5$ GPa

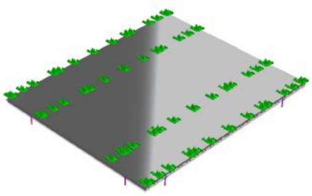
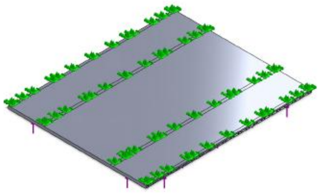
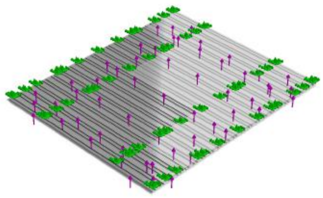
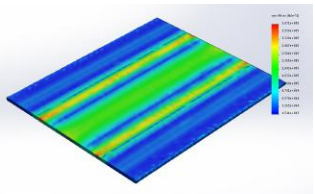
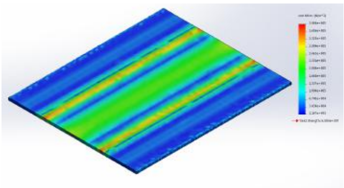
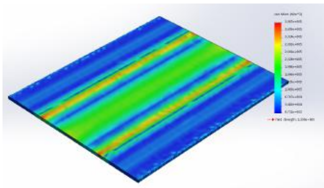
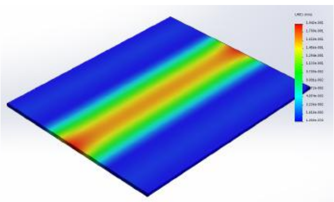
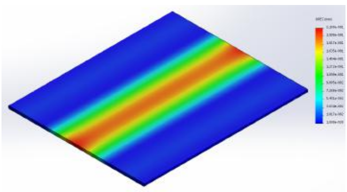
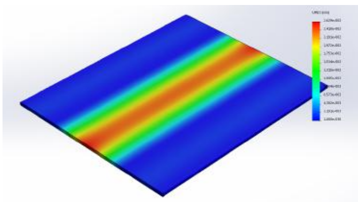
$= \dfrac{-55 \times 9.8 \times .41472^3}{48 \times 1.5 \times 10^9 \times 20015.78 \times 10^{-12}}$

$= -0.02668$ m

$= -26.7$ mm.

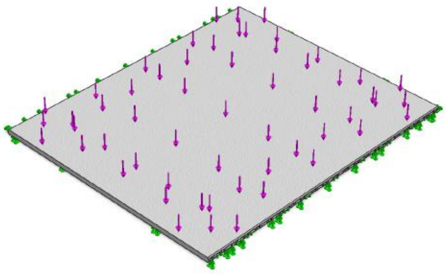
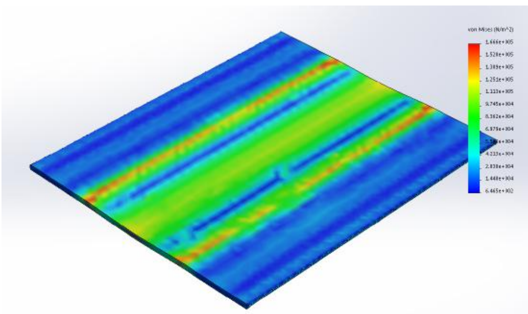
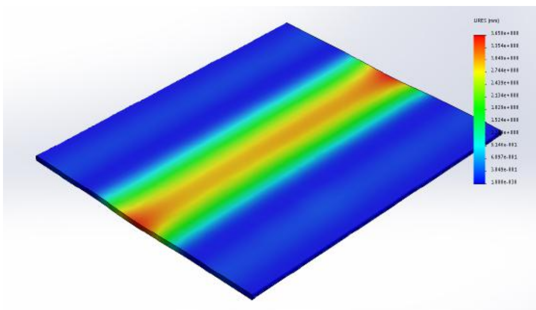
5.2.2 Finite Element Analysis of MiM

5.2.2.1 Panel A : Common Material Comparative Study

HDPE	Nylon 101	Nylon 6/10
Mass: 1.97602 kg Volume: 0.00207566 m^3 Density: 952 kg/m^3 Weight: 19.365 N  Force Applied = 539.95 N	**Mass: 2.387 kg** Volume: 0.00207566 m^3 Density: 1150 kg/m^3 Weight: 23.3926 N  Force Applied = 539.95 N	**Mass: 2.90592 kg** Volume: 0.00207566 m^3 Density: 1400 kg/m^3 Weight: 28.478 N  Force Applied = 539.95 N
 Max Stress = 387124 N/m^2	 Max Stress = 398756 N/m^2	 Max Stress = 398674 N/m^2
 Max Displacement = 0.194174 mm	 Max Displacement = 0.218037 mm	 Max Displacement = 0.0262915 mm

From the FEA it was found that the required thickness of the panels made from any of the three common polymer materials tested would lead to the Panels being too heavy. Hence a lighter material with a high strength to weight ratio was required.

5.2.2.2 Panel A : Delux Vinyl PVC

Delux Vinyl PVC	
 Force Applied = 269.80 N	**Mass:1.45296 kg** Volume:0.00207566 m^3 Density:700 kg/m^3 Weight:14.239 N
 Max Stress = 166595 N/m^2	 Max Displacement = 3.65849 mm

From the FEA studies with Delux Vinyl PVC material applied, it was proved that this lighter material deflected by 8mm with the full force applied. However, the situation of a child applying their full force of the desk was very extreme. Especially considering the play equipment would be in tunnel and other configurations that would not be climbed on. The FEA was considered with just the leaning force that would be applied, approximately 50% of the mass of the child. This showed much less deflection considering 3mm is very little across 600mm. Because the material is much lighter, the Delux Vinyl Twin Foam Wall PVC would still be most suitable for the panels.

6. Cost Analysis

6.1 Prep Pack

6.1.1 Unit Prices of Major Components

6.1.1.1 Rigid Panel (GD.SP-C.PP.1)

Injection Moulding HDPE cost approximately $0.38/kg with order quantities of 10,000 pieces.

The rigid has a mass of 1.07 kg. Hence each piece costs approximately $0.38 while being dependant on order quantity.

Ordering 10,000 pcs of GD.SP-C.PP.1 will cost approximately $3,800.00
- that will be more than enough for over 300 C.L.A.S.S units.

6.1.1.2 Leg Beam (GD.SP-C.PP.2)

Standard RHS with round corners of the dimensions selected cost approximately $13.50 per length. The standard lengths are usually 6.5 meters, and GD.SP-C.PP.2 is made from lengths of 320mm. Hence approximately 6 legs can be cut from a standard length of OEM RHS.

There are four leg beams per Prep Pack, thus to have enough legs for 10,000 Prep Packs, an order quantity of 40,000pcs would be required.

Each Leg Beam (GD.SP-C.PP.2) would individually cost around $2.25

Approximately 6,700 standard lengths of OEM RHS would need to be purchased, cut to size and machined. This would cost $90,450.00 if each length were purchased separately. For mass production of 10,000.00 pieces the material cost reduce significantly to around $2,250.00.

In this case each leg would cost $0.05625, and a set of legs for a Prep pack unit would $0.225.

6.1.1.3 Leg Plug (GD.SP-C.PP.2.5) and Rubber Boot (GD.SP-C.PP.3)

Both Leg Plug (GD.SP-C.PP.2.5) and Rubber Boot (GD.SP-C.PP.3) are small injection moulded parts from EPDM Rubber, and there are four in each Prep Pack Unit.

Assuming that at an order quantity of 40,000 pcs each of those parts cost $0.008/pc, The cost contributing to a Prep Pack unit would be $0.064

6.1.1.4 Textile Subassembly

As the textile material is readily available and does not require labour intensive processing, it is assumed that a complete textile assembly will cost approximately $0.047 when the order quantity is 10,000pcs.

6.1.1.5 Fasteners and Bushes and other Small OEM parts

It is assumed that all other small components ordered at quantities to produce 10,000 Prep Pack units, will cost around $350.

Hence it is assumed that all small items assembled to a single Prep Pack unit will cost $0.035

6.1.2 Cost of a single Prep Pack

With an order quantity of 10,000, as a fully assembled Prep Pack is calculated to cost:

PP_{cost} = $0.38 + $0.225 + $0.064 + $0.047 + $0.035 = **$0.751**

(This is an estimated price and based on an order quantity of 10,000 units where all or most parts would be manufactured in China to save costing)

6.2 Make-It-Module

6.2.1 Panels (A,B,C,D1,D2)

Sourcing the extruded sheet from Australian Sheet Traders: Deluxe Vinyl PVC: Twin Foam Wall PVC is $211.43AU per sheet.
With a sheet size 2440x1220, the Make-IT-Module could cut 8 of Panel A, 18 of Panel D1 and 24 of Panel D2 out of a single sheet.

Another Sheet could fit 4 of Panels B and C and another 6off Panel D1 and 8off D2.
This way, we would need 10 panels all together for the one C.L.A.S.S. unit.
This would cost $2114.3 AU however, with a 40% wholesalers cost, this would reduce to $1268AU.

Assuming these parts could be sourced from a cheaper manufacturer oversea, this cost would again, more than halve in cost, approximating $400 AU.
Assuming the Laser Cutting could also be done with the same supplier and it costs approximately $0.60 to cut each panel at a production cost of 1000 pieces each, the cutting cost for the panels for 15 Make It Modules would be $171.
Thus, the altogether cost of the panels for the Make-It-Modules is approximately $671, making each module panel material and assembly cost $38.07

6.2.2 Extruded Rubber

Assuming the rubber extrusion could be sourced from a cheaper supplier overseas, the cost of many rubber strips from Alibaba suppliers ranges from $0.05 per meter to $0.30 per meter. Assuming that the strip is of a higher quality and would be on the more expensive end of the spectrum, we will assume a cost of $0.30 per meter. The total length of strip needed for 15 Make-It-Modules is 45m (.6x4x15+.3x2x15). Thus the total amount of strip for a C.L.A.S.S. unit would be $13.50 and $0.90 per module.

6.2.3 Textile Exterior

Hook and Loop material sourced from overseas suppliers ranges from $0.20 to $2.00 per meter. Considering these are very large pieces, we will assume that it would be more expensive at $2.50 per meter. The pattern of the Make-It –Module is just over 2.8m. Thus for a single Make-It Module, the cost of the material would be $14.15. For the 15 modules to make up the C.L.A.S.S., it would be an overall cost of $212.25.

6.2.4 Assembly

The assembly of the Make it Module is very simple, only requiring sewing of the pattern, inserting the pre cut panels, sewing up the open side and then adhering the rubber strips.

Assuming there would be a production line for the different steps of the assembly to optimize efficiency, a single Make-It-Module should take no longer than 20 minutes from start to finish. Assuming a fair minimum wage of $20 and hour, the Make-It Module assembly would only cost $6.67. For the entire C.L.A.S.S. unit of 15 Module, it would be $100.

6.2.5 Overall Cost

With all of the above assumptions and adding a cost of approximately $4.00 for unconsidered parts and processes, the overall cost of a single Make-It-Module would be **$63.79**. Therefore, the cost for all the Make-It-Modules in the C.L.A.S.S. would be $956.85.

6.3 Class Cube

6.3.1 Unit Prices of Major Components

Assumed that the following items are manufactured in China at an order quantity of 10,000 pieces.

It is assumed that the standard RHS material lengths for one full frame, are cut and machined and welded for unit price of $18.50 per frame, and there is only one frame in each fully assembled C.L.A.S.S.

The Main Panel would cost around $9.80/pc

The Base Plate, Back and Door Panel would altogether cost around $12.30/pc

All OEM parts in quantities to make a full Class Cube would cost around $0.63 in total.

6.3.2 Cost of a Fully Assembled Class Cube

CC_{cost} = $18.50 + $9.80 + $12.30 + $0.63 = **$41.23**

6.4 C.L.A.S.S. Cost Comparison to other Drop-in Schools

6.4.1 Total Cost of a single C.L.A.S.S. unit

$\sum C$ = PP_{cost} (x 30) + MiM_{cost} (x 15)+ CC_{cost} + $Misc_{cost}$ = Total Cost of C.L.A.S.S. unit

$\sum C$ = \$0.751(x 30) + \$63.79 (x 15) + \$41.23 + \$27.50 = **\$1,048.11**

**Note: $Misc_{cost}$ is the Total Cost of Miscellaneous items such as Stationery, Whiteboard, Teachers Chair, Module containers etc.

6.4.2 Costing of other Drop in Schools

	Disaster Aid Temporary School	UNICEF's School in a Box	UNICEF's Early Child Development Kit	C.L.A.S.S
Cost	$2500 USD	$237AU	$247AU	**$ 1,048.11**
Capacity	1 x Teacher and up to 80 students	up to 40 students	up to 50 children	1x Teacher 30x students
Facilities	4 interconnecting tents, 1 blackboard, stationary school supplies and bags for teachers and students.	Stationary supplies, wind up solar radio, housed in aluminium box with integrated blackboard	Puzzles, art materials and toys.	Teacher's desk, Student's bags, stools and desks, play equipment, stationary and whiteboard.

6.4.3 Detailed Comparison

Comparing our C.L.A.S.S. cost of $1,048.11 to the School and Education packages in the table above, it is obviously much more expensive. However, it is important to note that it provides many more facilities that are not considered in the other packages. The C.L.A.S.S. provides an entire system with furniture, play equipment, stationary as well as personal student bags. This sort of system for disaster relief humanitarian villages is not yet in the market, so a true comparison is not available. However, considering that the C.L.A.S.S. is $1,451.89 below the cost of the $2500 Temporary school kit from Disaster Aid, it seems viable that this amount is put towards furniture facilities that are modular and may be used in another context.

7. Strengths, Weaknesses and Improvements

7.1 Prep Pack

7.1.1 Strengths

- The Prep Pack is an effective way of combining two products that are regularly used by school children, as it is multifunctional to serve as a Stool or School Bag.
- It has a storage capacity of 4525 cubic centimetres, which is more than enough space for a child to store stationery, school lunch and some belongings.
- It is easy to set up as a stool, and easy to pack up to be used as a bag.
- It can support a large child/small adult that weighs up to 60 kg with a safety factor of 2.
- It can be flat packed for efficient transporting and storage.
- Easy to Assemble without much use of complex or expensive machinery.
- Made from environmentally friendly materials and easily sourced OEM componentry.

7.1.2 Weaknesses

- The Prep Pack has aluminium legs due to the lightweight and good strength, however it does not look very suitable for a child.
- A child’s finger could get caught or cut on the leg runners.
- The stool is not height adjustable.
- There is no lumbar support for ergonomic sitting.
- There is no arm rests (not major issue as they can rest their arms on desks when working).
- The back straps are not adjustable in length.
- Once the Textile Subassembly is assembled to the Stool Structure Subassembly it cannot be disassembled and then reassembled in an easy manner, as stitching is required to seal the pockets.

7.1.3 Improvements

- Anodised aluminium legs would be a great way to achieve a good child-friendly colour while also sealing the metal to protect it from scratches and galvanic corrosion.

- Having some sort of foldout or extendable backrest for lumbar support would be ideal.

- Reducing the thickness of the Rigid Panel to reduce costs and weight.

- Designing a way to cater for three sitting heights would be important as kids come in all shapes and size with intermittent growth spurts between the ages of 5-10 years.

7.2 Make-It-Module

7.2.1 Strengths

- The MiM can be used as a height adjustable desk for working and studying.

- It can be manipulated into an array of different configurations to be used as play equipment and evoke creativity in the young minds of the users.

- Children can attach stickers and glitter to their shared MiMs to encourage sharing while being able to customise their own side.

- Easy to manufacture and assemble - Simplistic form utilises predominantly extruded materials, which is very cost effective and reliable.

- Ease of Disassembly after 2year life use.

7.2.2 Weaknesses

- Will get dirty in the environment with the loop material.

- Cannot fully support 55kg child.

- Cannot be disassembled and then reassembled in an easy manner, as stitching is required to seal the pockets.

- It is too heavy for children to carry the entire unit by themselves.

- When making large structures to replicate playground climbing set ups, it can be dangerous.

7.2.3 Improvements

- Find a better material that is still lightweight, yet strong enough to fully support child of 55kg. (May include support rods through material).
- Reconsider sizing to be more easily manoeuvred by a single child.
- Removable Cover so it can be washed.

7.3 Class Cube

7.3.1 Strengths

- Durable enough to withstand transportation and store the internal components in a safe and secure manner.
- Simple functionality, in terms of converting from simply a transportation container to a storage device and finally to a usable teachers desk.
- Centralises all the necessary components that are required in a classroom.
- Fits on any standard pallet, sized 1m X 1m, and above.
- Can be rolled around due to the castor wheels.
- All componentry is made from readily available and sustainable materials

7.3.2 Weaknesses

- Very heave due to the amount of cross members welded to the metal frames.
- Too tall to be considered an ergonomic work desk.
- Can’t be stacked on a pallet during shipping due to maximum height limits.
- When in desk mode the working surface (top of housing) is ergonomically too high for the teacher to use comfortably.

7.3.3 Improvements

- Addition of straps/hold-down plates for some of the internal components.
- Can make frame cross-section sizes smaller to reduce weight.

- Internal component layout could still be improved further.
- Be more space efficient and make working surface an appropriate height for the teacher to work/write on.

7.4 C.L.A.S.S.

7.4.1 Strengths

- It is a compact, drop in classroom that centralises elements needed in a learning environment while facilitating basic technology and needs.
- Stores enough bags/stools and desks and other accessories to provide up to 30 children essential tools to create a learning environment.
- It encourages social connectivity as children can play together and be creative with the modular MiMs to construct various playground structures in an array of different configurations.
- It has been designed for easy transport, as the housing can be rolled around with wheels, and internal modules can be extracted and carried to make loaded and unloading easy.
- The system has been designed to last for at least 2 years, and can be reused several times over. If parts go missing or failed, all products/elements of the system can easily be disassembled to replace componentry in a sustainable manner. Furthermore materials used a recyclable so when parts reach the end of life stage they can be disposed of in an environmentally friendly way.

7.4.2 Weaknesses

- When the unit is fully packed with the modules it is too heavy for four men to lift and can be considered immobile.
- The system is designed to only be used indoors, where as in some cases schools/classes in humanitarian villages may be limited to outdoor settings.
- As it has been specifically designed for classes of 30 children, it would be ideal to have extra/spare parts such as additional Prep Packs and MiMs.
- The system does not include any electronic or mid/high-tech equipment.
- The teacher and students are limited to hand writing on books, paper or the white board provided.

7.4.3 Improvements

- Reduce the weight of all subassemblies and parts, to reduce the overall weight of the system.

- Possibly include a folded water proof sheet that can be set up like a large tent to allow classrooms to be set up outdoors.

- Be more space efficient in order to include spare Prep Packs, MiMs and other important equipment (to be suitable for classes of larger numbers or have extra subassemblies/parts if some fail, break or are lost)

- Include some cost effective electronic products that aid in learning, to effectively facilitate technology. Possibly include a laptop for each child and at least one for the teacher.

- Possibly include low-tech tablets or smart devices that children can use for writing/drawing/calculating and much more. This will remove the need for including consumables (pencils, rubbers, notebooks etc.)

- Introduce more products that encourage social interacting, friendship making and the development of teamwork skills.

8. Conclusion

When reflecting on the overall system as a drop in classroom for humanitarian villages, C.L.A.S.S. is a cost effective, centralised array of easy to transport products that will aid users in the areas that we have designed for.
C.L.A.S.S. provides essential elements needed for recreating a learning environment, while providing items that children can take home and experience as sense of belonging after they have lost so much. The system encourages social connectivity by supplying products for children to play with and use together.
To further develop the overall system and the elements within, reducing weight of componentry wherever possible, along with being more space efficient will ultimately reduce the overall cost even further and make it more mobile and transportable.
With the fundamental goals of the return brief achieved, C.L.A.S.S. is overall successful; as it is an economically viable, sustainable and multifunctional array of products that can ultimately be used to provide a learning environment for youth disaster victims while promoting social interaction.