

Soap Daddy Inc
Integrating Project ACHA4008

University of Wales Trinity Saint David

Wales Institute of Science and Art



Prifysgol Cymru

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Trinity Saint David

Soap Daddy Inc

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Olly Gillson, Liam Davidson, Harry Rogers, Ollie Wilson, Conor Jenkins, Tomos Cole

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1 Introduction

Our team consists of six members, each taking on a varying number of roles through the project lifespan. We first decided as a group to call a meeting and assign some defined roles to each member, after a short discussion and with everyone in agreement it was settled as follows.

Oliver Gillson – **Team Lead, Report Consolidation, Minuets**

Liam Davidson – **Head of Design Specifications & Competition Regulations, Minuets**

Conor Jenkins, Harry Rogers – **Final Design Drafters**

Harry Rogers, Oliver Wilson, Conor Jenkins, Tomos Cole, Oliver Gillson, Liam Davidson – **Materials Research, Design & Report Reviewees**

Other roles were designated during the project, for example the team was tasked to produce rough drawings of their expectations from the design of the soap box. These rough drawings (Figure 1-5) were passed onto Conor who compiled them and took the best areas from all designs to finalise a master drawing (Figure 6). A team meeting was called when this finalised drawing was completed to allow the group to voice any concerns, the team moved on to researching the costs, pros, and cons of different materials in the four main areas of the soap box construction: chassis, steering, braking and body.

Harry Rogers took on the role of creating a 1st revision final draft after some changes were made (Figure 7).

Our main point of contact was a Teams group, used for storage of all documents, general chat between members and used to organise meetings between the group and individuals. Minuets of meetings were taken so they could be referred to and a Gantt chart was created to produce a visual timeline of the project.

2 Minuets

2.1 15.11.2022

Meeting called by: Olly Gillson

Type of meeting: Catchup/Introduction

Note taker: Olly Gillson

Timekeeper: Olly Gillson

Attendees: Olly Gillson, Liam Davidson, Harry Rogers, Ollie Wilson, Conor Jenkins, Tomos Cole

Minutes

Agenda item: Introduce Tomos

Presenter: Olly Gillson

Discussion:

Olly - "We're here to introduce Tomos to the group, everyone this is Tomos, Tomos this is Liam, Harry, Ollie and Conor."

Tomos - "Hi everyone"

Olly - "To get you up to scratch Tomos, everyone has drawn a rough sketch of what they would like the soap box to look like. We've then called a meeting and discussed a final drawing that Conor has finalised. These are available in the teams files section for you to look at."

Olly - "Is everyone happy to move onto the product research?"

Everyone - "Yes"

Olly - "We all have different areas to research, what area would you like to research Tomos?"

Tomos - "Body sounds good"

Olly - "Okay if you can gather 3-4 materials, write about their pros and cons research what the costs would be. Compile the information and we will come back in the next few weeks for a catchup."

Conor - "Could I look at researching into the body also?"

Everyone – Agrees

Conclusions:

Tomos introduced and will be working on the body materials research with Conor.

2.2 16.01.2023

Meeting called by: Olly Gillson

Note taker: Olly Gillson

Timekeeper: Olly Gillson

Attendees: Olly Gillson, Liam Davidson, Ollie Wilson, Harry Rogers

Minutes

Agenda item: Post-holiday catchup

Presenter: Olly Gillson

Discussion:

OG -This is just a meeting to catch up with everyone and see how we are getting on with materials research. If everyone is okay, I would like to have some work ready to be compiled into the report by Wednesday 18th Jan.

Everyone - Agrees 18th hand in is acceptable

OG – Does anyone have anything else to mention?

Harry – How much work are you putting into the materials research?

OG – I have done about 300 words detailing the strength, weight, joining methods and price of each material.

Remember it needs to be correctly referenced.

Harry – Okay great same here.

OG – Liam are you able to research the diameter of the axel we will use so I can get a quote for the right diameter tubing to use for the axel casings.

Liam – Yes, I can get that to you by Wednesday.

Ollie – Just to confirm with the steering method that I am comparing steering wheel vs handlebars.

Everyone – Yes

Ollie – How would I reference that

OG – as its opinion based and you aren't stating any facts about the materials used, I don't think you will need to reference a lot. Just make sure if you do suggest something factual that it is backup by supported material.

OG – If no one has any more questions we can end the meeting, ill setup another meeting for Friday to catch up and compile any more information, otherwise just ask in the chat and we can all help.

Everyone – Agrees no more issues present

Call ends.

Action items

Finish off materials research

Person responsible

Team

Deadline

18/01/23

2.3 18.01.2023

Meeting called by: Liam Davidson

Note taker: Liam Davidson

Timekeeper: Liam Davidson

Attendees: Liam Davidson, Olly Gillson, Oliver Wilson, Harry Rogers.

Minutes

Agenda item: To Discuss our findings and any issues.

Presenter: Olly Gillson

Discussion:

OG – As agreed today is the hand in for everyone's research, how has everyone been getting on and what stages are you at?

Liam - I have submitted my research on the brakes and the mounting of the rear wheels, Ollie how are you getting on with steering and mounting of the front wheels?

OW – I've just handed my research into the team's files if we wouldn't mind having a read over it, Ill share my screen, Liam regarding the operation of the brake we are not mounting it to the steering wheel with a lever, are we?

Liam – No, it will be a foot operated pedal mounted to the floor.

Everyone – Agrees with Ollie's steering method and research produced.

Liam – I noticed our main drawing has handlebars, we are going to need to do a final drawing.

OG – also the dimensions of the cart need to be put into the drawing.

Harry – Id be happy to give that a go?

OG – would you be okay handing that in on Friday 20th?

Harry – yes that is fine. I will share my screen as my materials research is done for the chassis and would be good to go over it with everyone here.

Everyone – happy with the work provided and use of references.

OW – Olly do you need me to do anything else as I'm free over the next few days?

OG – We need someone to work on aerodynamics?

OW – I can do that, it relates to the stuff I have been doing with the MCR team, would a hand in on Friday 20th be okay?

OG - Yes, that's perfect.

OG – Has anyone got anything else to add?

Everyone – no, I think we are all good if there is anything else put it in the chat and we can all help.

Call ends.

Action items	Person responsible	Deadline
• Aerodynamic research	Oliver Wilson	20/01/22
• Final Drawing	Harry Rogers	20/01/22
• Meeting minutes	Liam Davidson	20/01/22

3 Gantt Chart

Please follow link below.

[Gantt Chart](#)

4 Aims

Ours aim for the project is to design a winning soapbox using a range of materials that we saw fit for the application.

As a group, we decided on the overall body design and agreed that the structural and mechanical elements should be affordable yet high quality, enough to ensure a structurally sound and mechanically efficient soapbox. To provide us with options each person was tasked with researching multiple materials.

5 Design

Our design incorporates a large wheelbase of 1m this allows for maximum stability when cornering whilst complying with regulations. An aerodynamic design approach has been adopted to assist with minimal drag coefficient and steering and braking has been researched to provide the driver with the optimal amount of control and stopping force. These areas are discussed in detail further on. Figure 1-5 are the group's first draft concepts.

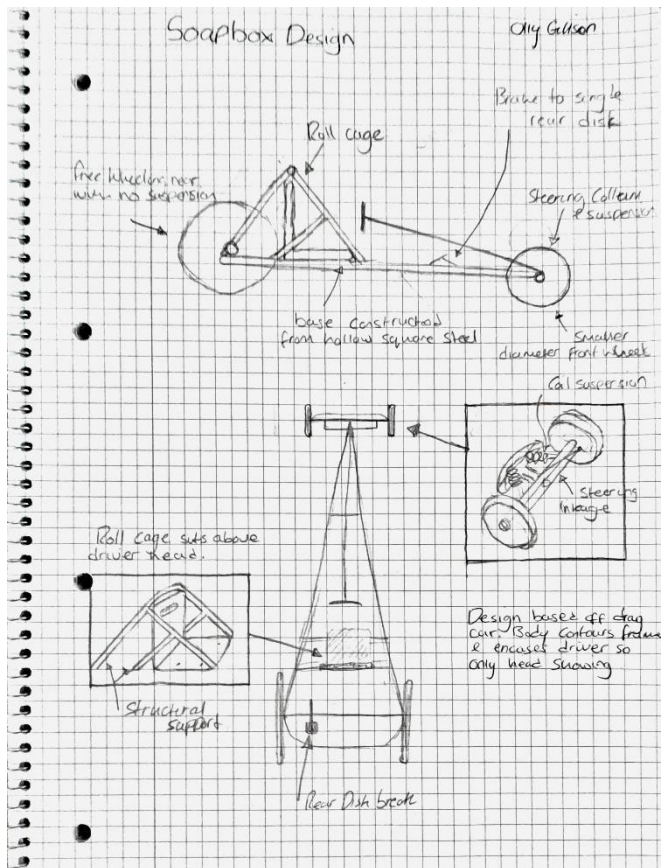


Figure 1: Oliver Gillson

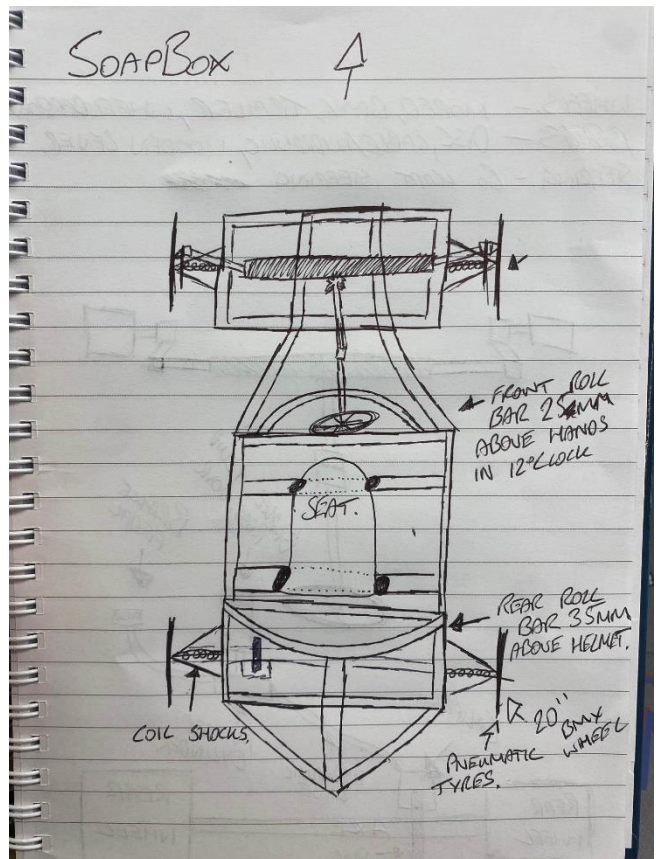


Figure 2: Liam Davidson

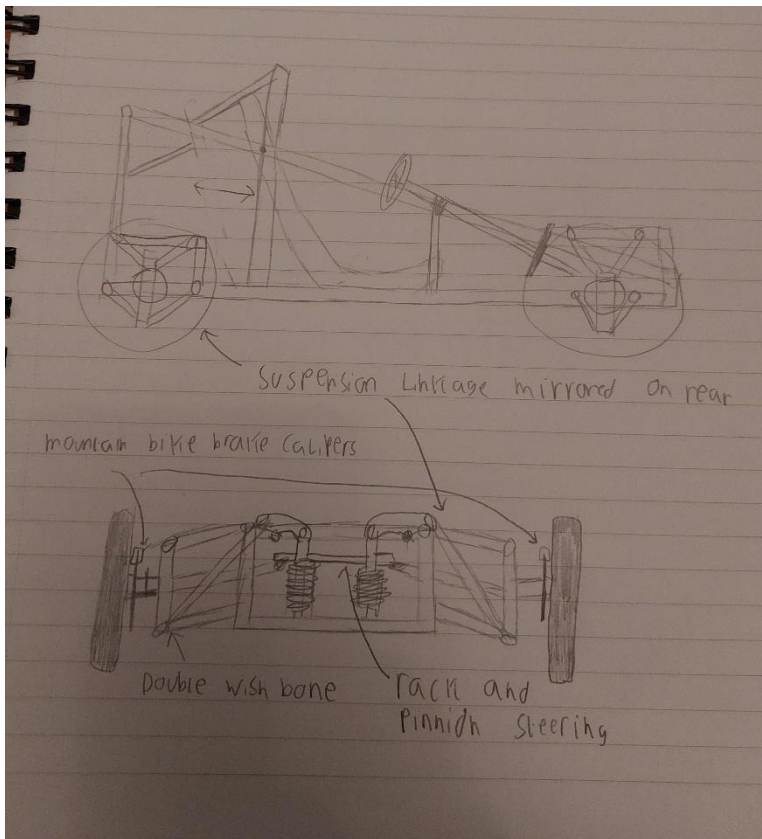


Figure 4: Harry Rogers

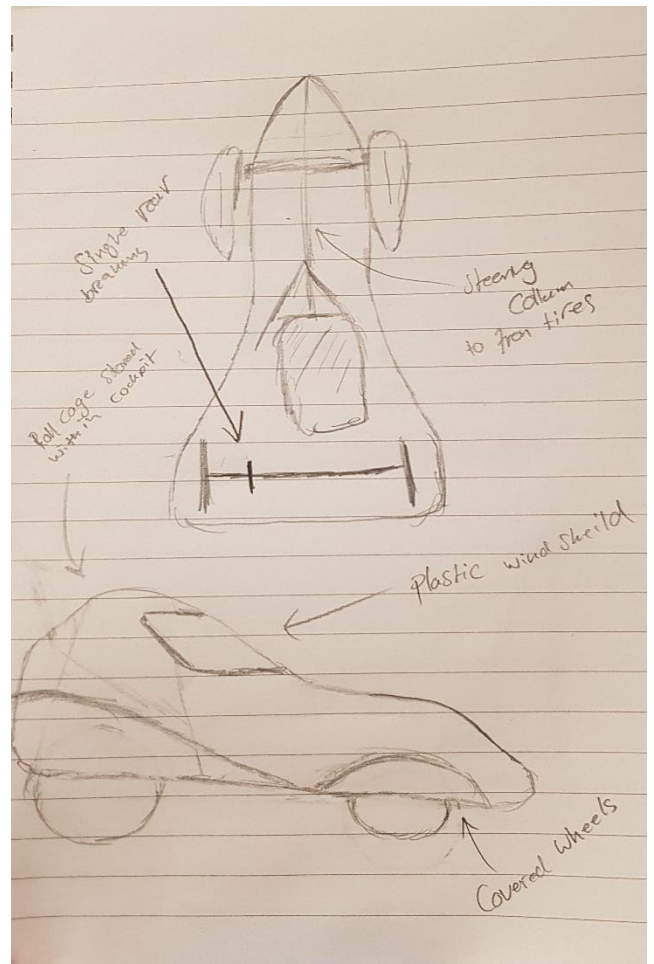


Figure 3: Oliver Wilson

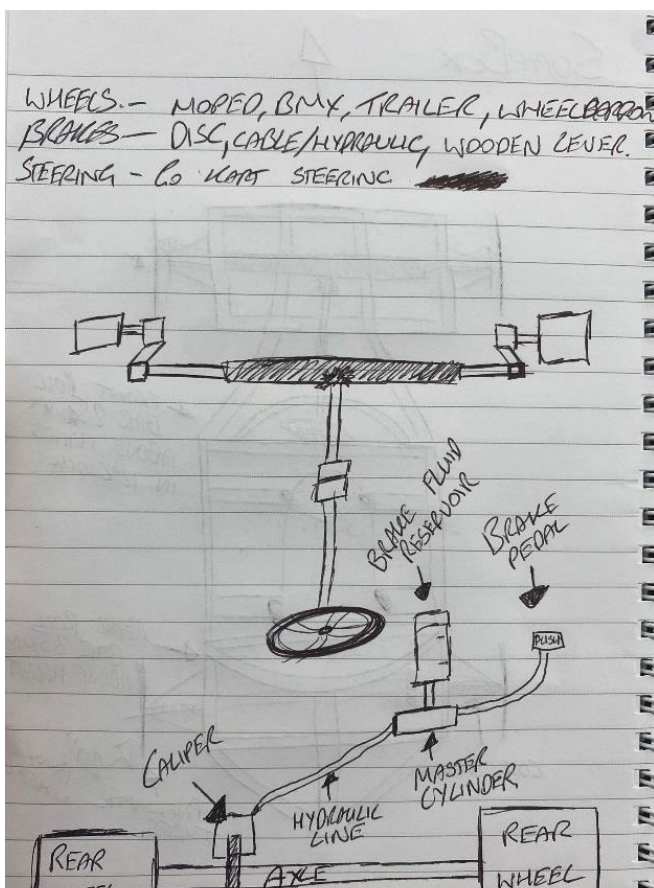


Figure 5: Liam Davidson

5.1 Final Design

A meeting was called where all designs were taken into consideration and the group discussed features from each design that would make the final draft. The final design was drawn up by Conor Jenkins. As the project continued some changes to the steering were agreed and soapbox dimensions finalised, this resulted in a slight change of design which was fulfilled by Harry Rogers.

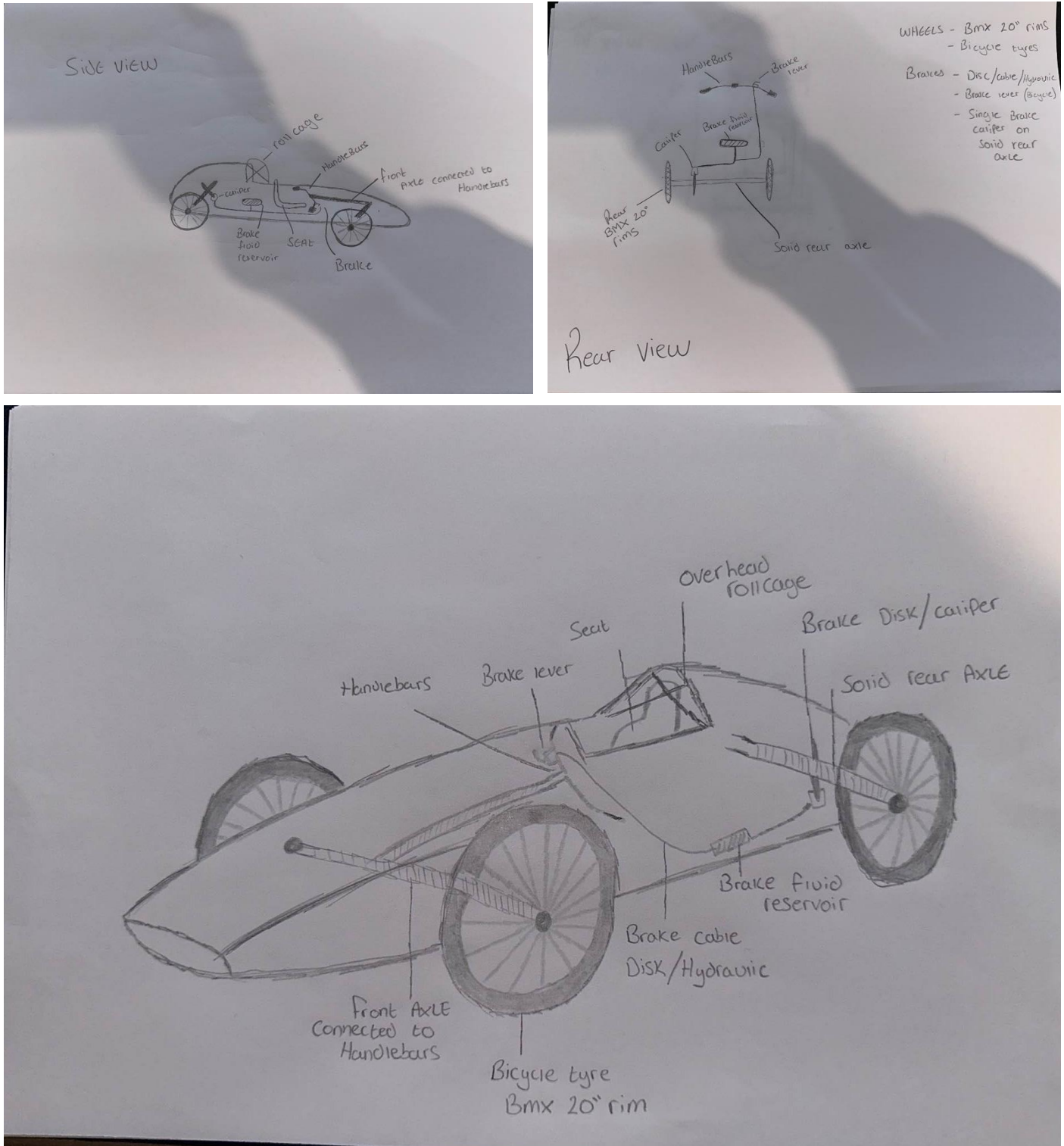


Figure 6: Final Draft (Conor Jenkins)

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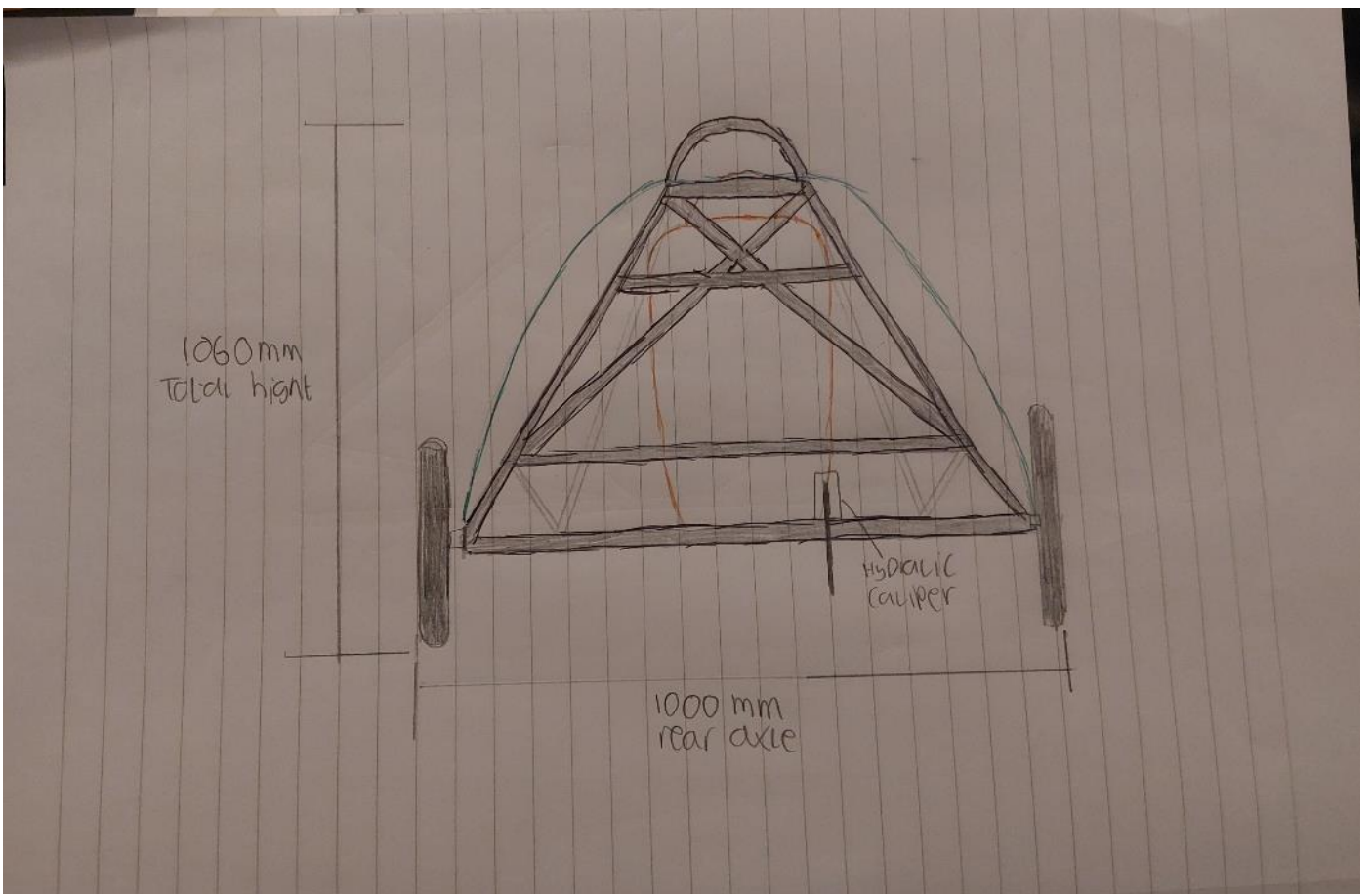
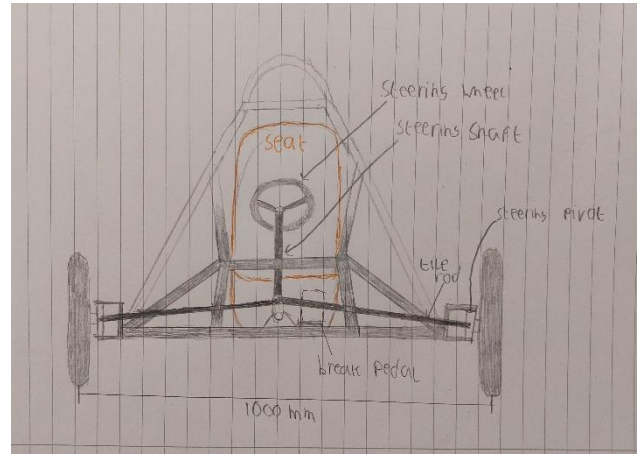
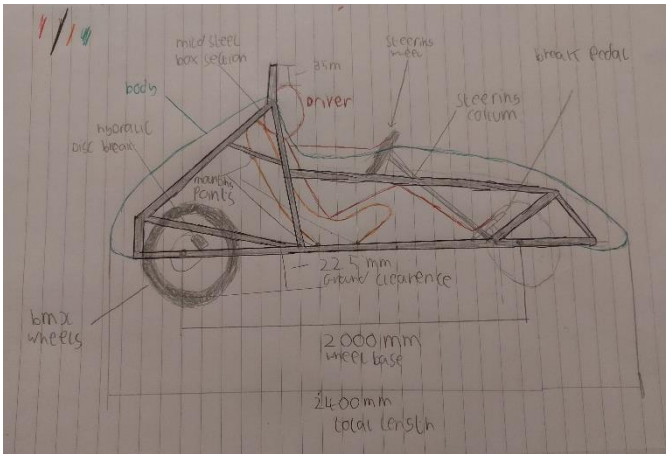


Figure 7: Final Draft 1st Revision (Harry Rogers)

6 Materials and Cost Research

6.1 Chassis

6.1.1 Steel

With a tensile strength ranging from 250-1300MPa (Higgins, R 2010) and a relative density of 7.8kg/m³ (Bolton, Higgins 2020) mild steel will provide a structurally robust frame whilst keeping weight to a minimum.

Hollow section mild steel could be used as this will provide good structural integrity without being cumbersome and is easy to work with using simple tools and methods.

Steel Express, a Swansea metal dealer provides three types of hollow section mild steel. Rectangular, square, and circular. Square, or rectangular section could be used for the main chassis of the soapbox taking up the structural load and supporting the rider, any internal mechanisms, and the body. To comply with regulations circular section can be used for the roll cage which should be strong enough to withstand an impact and keep the driver safe.

Arc-welding is the most popular form of joining method for use with metal alloys. "In this process, a metal electrode serves both to carry the arc and to act as a filler-rod which deposits molten metal into the joint" (Bolton, Higgins 2020, pg. 292). Welding will be our preferred method of joining with the option of nut and bolt if the application calls for it.

Box Section - [Mild Steel Square Hollow Section – Steel Express](#)

50mmx50mmx3mm (6.4m length) - £125.46

Rectangular Section - [Mild Steel Rectangular Hollow Section – Steel Express](#)

75mmx50mmx3mm (6m length) - £89.70

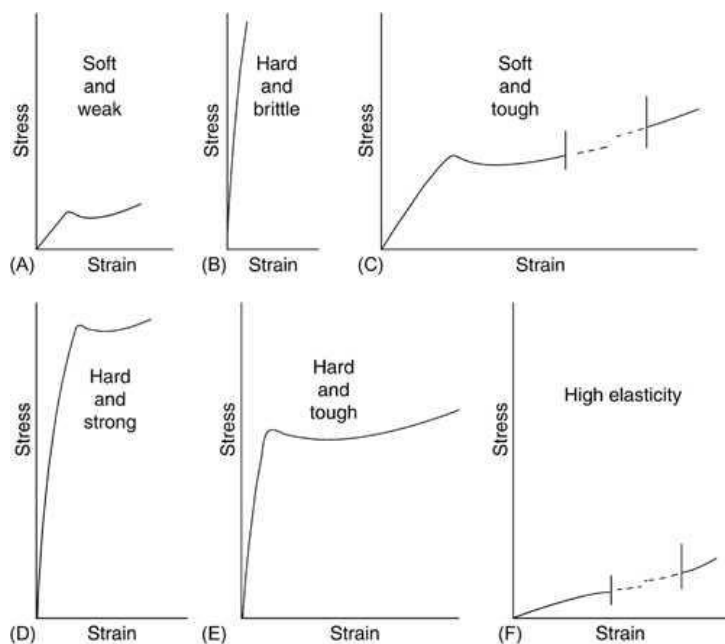
Circular Section - [Circular Hollow Section – Steel Express](#)

42.4ODx3mm (6m length) - £45.50

From research, mild steel looks to be a strong, light, and cheap material to use for a chassis. This is backed up by its wide use in the automotive industry. Due to mild steel's high fracture toughness of 140MN/m^{3/2} (Ashby & Jones, 1996) it is resilient against damage from crashes.

Welding skill could prove an issue here as the welds will provide part of the structural integrity and if done incorrectly could cause issues.

6.1.2 Rigid PVC



"Plastics are less strong than steel but offer a lower relative density of 0.9-2.0kg/m³ which when compared with some metals boasts a favourable strength to weight ratio." (Bolton, Higgins 2020, pg. 241). MKM Plastics provides a tensile strength of 47MPa on their extruded plastics. (MKM Plastics Data Sheet, 2023)

Figure 8 shows "Types of stress-strain diagram for different polymer materials. (A) Low elastic modulus, low yield stress, e.g. PVA and PTFE. (B) High elastic modulus, low elongation, e.g. PF, PMMA and PS. (C) Low elastic modulus, low yield stress but high elongation and high stress at break, e.g. PE and plasticised PVC. (D) High elastic modulus, high yield stress, high tensile strength and low elongation, e.g. rigid PVC and modified PS. (E) High elastic modulus, high yield stress, high tensile strength and high elongation, e.g. nylons and polycarbonates. (F) Very low elastic modulus, low yield stress and low tensile strength but very high elastic elongation, e.g. natural rubber and other elastomers." (Bolton, Higgins 2020, pg. 241).

Taking Figure 1 into account, it seems chart D (rigid PVC and modified PS) looks to be the best fit for the job of supporting the rider and soapbox with its high yield stress, high tensile strength, and low elongation. Rigid PVC is widely available in box and circular hollow section so would be the preferred method.

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MKM Extrusions are a UK manufacturer of various plastic products, they supply hollow square and circular sections.

Hot gas welding can be used to join plastic, in this process “a thin filler-rod is used and is of the same material as that of the workpieces. This process is used widely in the building of chemical plant, particularly in rigid PVC.” (Bolton, Higgins 2020, pg. 299).

Box section - [Plastic square tube 50mm x 50mm x 3mm white \(mkmplastics.com\)](https://www.mkmplastics.com/)
50mmx50mmx3mm (25x3m lengths) - £420.01

Circular Section - [Plastic tube rigid 50mm x 3mm white \(mkmplastics.com\)](https://www.mkmplastics.com/)
50mmx3mm (25x3m lengths) - £264.60

Although PVC is light and relatively strong the team has doubts it would happily support the weight of the cart and rider as well as supporting any crashes or jumps.

MKM Plastics data sheet states their PVC softening point as 78°C this poses the question of whether the heat of bearings and brake elements will cause an issue.

6.1.3 Carbon Fibre

Carbon fibre has a tensile strength ranging between 100-1800 MPa depending on how it's woven and laid up, and a density of 1750 Kg/m³ (Bolton and Higgins, 2020). In this application, carbon fibre could either be used to construct a monocoque chassis or with premade tubes to create a space frame. To create a monocoque sheets of prepreg carbon fibre are cut to shape and laid up inside a mould, usually machined from aluminium, the mould is left to cure inside a heated pressurised chamber called an autoclave. The direction of the fibres and the number of layers in different parts of the chassis can be changed to alter the characteristics of the frame. This allows for optimisation of the chassis weight and stiffness to best suit the application. alternatively

Premade carbon fibre tubes can be used to create a space frame chassis. To connect tubes, the joints can be wrapped with fibres of uncured prepreg carbon. This is the strongest and lightest way to join the tubes and allows to true the characteristics of the joint. (Fleischer and Schaedel, 2013).

Prepreg carbon fibre sheet - www.easycomposites.co.uk
£32.33 – £62.70 SQM depending on the weave of the material

Carbon fibre tubes - www.easycomposites.co.uk
£10.60 - £43.25 per meter depending on the diameter

Carbon fibre would be the perfect material to create the frame with as it has an exceptional strength-to-weight ratio and can be manipulated to create the characteristics wanted from the frame, like flex and stiffness. The largest cost implication with carbon fibre is caused by the manufacturing process. The tooling and moulds used are expensive as is outsourcing manufacturing.

6.1.4 Wood

Wood has a tensile strength of between 6-100 MPa parallel with the grain (dependent on the genus). And a density of 1500 Kg/m³ (Bolton and Higgins, 2020, pg. 281). This suggests that thicker and heavier sections will need to be used to make the chassis strong and resilient. It also shows that the geometry of the frame will be very important to achieve the desired strength. Sections of 2"x4" wood would be used as it is common to source and will give a good strength-to-weight ratio. It is also inexpensive to buy and will be easy to work, with common tooling being easy to use.

To join the sections, we will use a combination of wood screws and bolts through predrilled holes. This method will be strong enough if time is taken in the design process to make the joints orientated in a strong and solid way to avoid flex and breakages.

47mm x 100mm x 4.8m Treated Sawn Timber - www.travisperkins.co.uk
£19.64 each

5 x 100mm Countersunk Pozi Cutter Yellow Wood Screws - www.travisperkins.co.uk
£32.35

Wood is an easy-to-source, easy-to-work and strong material that is commonly seen in soapbox design. Weight may prove to be an issue due to the size of the wood lengths used to safely support the rider and ensure structural stability if a crash was to occur.

6.2 Fairing Materials

6.2.1 Carbon Fibre Composite

With a relative density of 1.70kg/m³ and a tensile strength of 3.5GPa (Bolton, Higgins 2020, pg. 281) carbon fibre can be seen as the top choice when creating a soapbox fairing. Its light yet strong properties allow for safety and structure whilst keeping weight to a minimum.

www.easycomposites.co.uk provide a range of composite sheets and epoxy resins to allow consumers to engineer their own carbon fibre designs. Prices start at £12 /sqm for the most basic weave design and exceed £50/sqm for more intricate weaves. Epoxy coatings are also supplied at an average of £19.38/kg.

Carbon fibre is a great choice for fairing design as can be seen in the professional racing world, however it comes at a high price point, and includes lots of labour and a range of specialist tools.

6.2.2 Glass Fibre Composite

"S" class glass fibre provides similar mechanical properties to fibreglass. With a relative density of 2.6kg/m³ and a tensile strength of 4.6GPa (Bolton, Higgins 2020, pg. 281) it provides slightly more strength but an almost 1kg/m³ density gain.

www.cfsnet.co.uk provide glass fibre materials to the UK. Their most expensive twill sheet starts at £4.88/m and a 3.25kg kit of epoxy resin and hardener costs £62.06.

Although slightly heavier than carbon fibre, glass fibre is much cheaper to purchase, and does not require as many specialist tools. It is worth mentioning that glass fibre, like carbon fibre, needs a mould to cure to hold shape. This needs to be considered when budgeting time and costs.

6.2.3 Aluminium

"6061 aluminium alloy has a minimum tensile strength of 290 MPa and a minimum yield strength of 241 MPa. With a thickness of 6.35 mm or less." (Ferguson Perforating).

Aluminium is a very strong and lightweight metal. It has a high strength-to-weight ratio. This makes it an ideal material for many applications, such as aircraft and automobile parts, construction materials, and packaging materials.

"The heat-treatable alloy 6061, made of aluminium, is stronger than alloy 6005A. It boasts good resistance to corrosion and is easy to weld, though the strength in the welded areas may be lowered." (aalco, 2023).

Aluminium Sheet – www.themetalstore.co.uk
2500mm x 1250mm x 1.5mm - £132.00

6.2.4 Plywood

The tensile strength of plywood is 27.6 to 34.5MPa (civil jungle) Plywood is an engineered wood that is made by gluing together several layers of wood veneer with their grain's perpendicular to each other. This cross-graining gives plywood its stability and strength. In general, hardwood plywood is stronger than softwood plywood. The thickness of the plywood also plays a role in its strength. The grade of plywood also has an impact on its strength, where A-grade is the most durable and strongest, and D-grade is used for non-structural purposes. (Chinchalkar). In summary, plywood is a widely used and versatile material in construction due to its stability and strength, and the thickness and grade of the plywood play a significant role in determining its strength and weight.

Hardwood Plywood Sheet – www.nottagetimber.co.uk

2440mm x 1220mm x 3.6 mm - £15.16

7 Dynamics & Driveability

7.1 Braking

The teams first thoughts on braking and wheels was to use bicycle wheels with rim brakes with levers attached to handlebars, this was changed after it was noted that the performance of rim brakes may not be suitable for the speeds of the course, they would also coincide with the teams preferred steering method. The discussion turned to using mountain bike disc brakes, again the initial thought was operating both brakes from the one lever, we knew we wanted to choose disc brakes due to their cooling advantage and consistent performance in various weather conditions which led us onto our final design of using a singular disc brake attached to the rear axle and operating using a hydraulic brake pedal operated by the drivers foot, this design is often seen on racing karts that regularly exceed speeds of 60mph. This allows a brake disc carrier to be clamped on the axle with the use of a 6mm keyway. To allow the axle to rotate freely 2 clamping axle bearings will be used along with 2x 6mm keyways. To mount the axle to the chassis 2 bearing housings will be used. The above aligns with the rules and regulations under General Conditions, 2.5.

7.2 Wheels

The team were discussing several different options for wheels. As the rear axle is from a kart naturally the first discussion was to use kart wheels, this brought some doubts about meeting the advised 50mm ground clearance as stated in the regulations and issues with the jumps on the course.

The discussion was then to use pit bike rims which would meet the ground clearance required and would be suitable to support the driver and soapbox, however doubts were raised about the excessive weight and the costs of pit bike rims and tyres.

The team came to the decision that 20" BMX rims and tyres would be sufficient, this rim and tyre combination can support the soapbox and rider weight but also the jumps of the course, the pneumatic tyres will meet the regulations and the diameter of the wheel will meet ground clearance, this is a cheaper solution than the pit bike wheels and weigh less.

It is worth noting that the wheels will require the bearings removed and an adaptor made to bolt the wheel to the axle.

Item	Amount	Cost	Source
25X970mm Axle	1	£55.80	www.kartpartsuk.com
6mm Keyway	3	£1.80	www.kartpartsuk.com
25mm Disc Carrier	1	£27.54	www.kartpartsuk.com
25mm Axle Bearing	2	£7.74	www.kartpartsuk.com
Bearing Housing	2	£7.44	www.kartpartsuk.com
Two piston brake calliper with brake lines, brake disc and master cylinder	1	£150	www.kartpartsuk.com
20" BMX Rims	4	£23	www.ebay.co.uk
20" Street Tyre	4	£6.99	www.sourcebmx.com
20" Inner Tube	4	£2.99	www.chainreactioncycles.com

Table 1 Cost breakdown of wheel and axel components

7.3 Steering

7.3.1 Pulley Method

The methods of steering we use in the soapbox should be simple to construct, cheap to source and provide adequate control for the speed and terrain encountered. The soapbox regulations state, "The course is 500m long with a decent of 50m expecting to reach speed in the region of 40-50mph." The steering should be selected to suit the above condition.

The first method that can be used is a cable pulley steering system, this method uses a series of pulleys and eyebolts to manipulate the front axle.

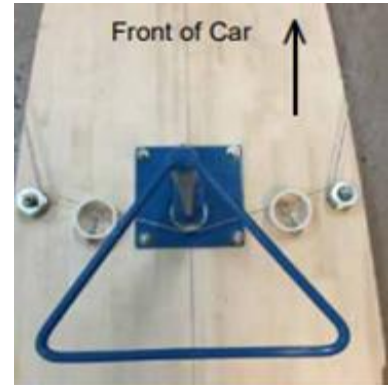


Figure 9: Soapbox Derby Masters Car (2017)



Figure 10: Soap Box Derby Masters Car (2017)

The system can be adjusted by increasing the tension of eyebolts, this can easily be done between runs to refine the steering. This method is also very cheap using easily accessible materials. The steering is controlled by a handlebar such as the one in Figure 9.

7.3.2 Pivot Method

The second method is a pivot steering method with axels mounted to wheels. This method involves less components and doesn't require tightening like the cable pulley system (Figure 11). This method allows for a steering wheel to be used as it is connected to a single pivot point, using a steering wheel instead of a handlebar would mean a foot pedal is needed for braking. This will add more complexity to the setup but will benefit the handling of the kart for the driver.

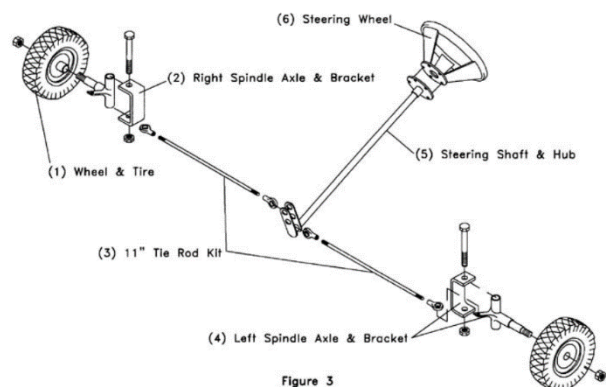


Figure 3

Figure 11: buildyourowngokart (2000)

8 Aerodynamics

"The most important factors that may affect the overall speed of the car have been determined to aerodynamic drag coefficient, the frontal area, tire and bearing rolling resistance, vehicle weight, and centre of gravity weight distribution." (Yager, & Cullen, 2015).

Aero efficiency and drag coefficient has been a centre point for the design of the fairings on the soapbox. The team decided a wedge shape nose that is thinner at the front tapering to a larger rear will assist with airflow over the entirety of the body. Diffusers, splitters and wings were discussed but it was agreed that the soapbox will not be travelling at high enough speeds to benefit.

Dependant on the efficiency of the kart in its current design a few changes could be made. A windscreen could be fitted in-front of the driver to further deflect air current and wheel covers could be fitted to reduce drag. However it is questionable how much of a difference these changes will make and how much weight they will add.

The driver has been strategically positioned close to the centre of the vehicle to assist with weight distribution.

9 Materials Conclusion

The team agreed to meet and came to an agreement on the materials that will be used for the chassis and fairing as well as the steering and braking methods. The choices were determined on the group's opinion of ease of useability, relating back to relevant hands-on experience within the team members as well as affordability. Below are the agreed materials.

- Chassis – Steel
 - Steel has best strength to weight and price range. It's also easy to work with and the joins should prove strong enough to support the needs of the soapbox.
- Fairing – Plywood
 - A thinner plywood will allow curves and bends to be achieved, helping with aerodynamics.
- Steering – Pivot Method
 - The pivot method will allow for accurate steering and feedback.
- Braking – Single disc hydraulic controlled by foot pedal.
 - Allows the driver to maintain wheel control.
- Wheels – 20" BMX wheels and tyres
 - Conforms with 50mm clearance regulation and allows for stability and good steering control.

More work and research need to be done to refine the cost of the soapbox, but the figures mentioned in chapter 6 and 7 give an approximation of the parts and their prices.

10 Group Evaluation

The project started off strong with an instant group forming and first meeting taking place not long after the assignment hand out. Drawings were produced within good time to allow decisions to be made on the areas of research. There was some slack over the Christmas period which caused a backlog of work, but this has been met over the few early weeks of January with the team pulling together to achieve a high amount of quality research in the specified areas.

The group has worked well as a team and has taken the time to listen to others concerns and allowed for respectful discussions on differing opinions. The delegation of work has been fair allowing everyone to have the ability to take part.

The information provided above gives a great outline on the materials that could be used and consolidates their pros and cons allowing for an easy final decision to be made. A CAD model of the soapbox will be the next step in determining whether the design and materials we have chosen would be suitable, the model will also assist in a more accurate representation of the materials cost.

11 References

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