

University of Wales Trinity Saint David

Institute of Science & Art



Prifysgol Cymru
Y Drindod Dewi Sant
University of Wales
Trinity Saint David

LMJ³ Soapbox Car Project

Integrating Project (ACHA4008)

Luke Dyas (2104531), James Vine (2106621), Michael Carlo Aganon (2103745),
Joshua Davies (2104322), Joshua Thomas (2115652)

Team LMJ³

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1 Introduction

Defined by the Guinness Book of Records, a Gravity Racer is 'a motor-less vehicle, capable of holding a driver which has no form of onboard propulsion' (Ekin,2014). Although the official term may be a Gravity Racer, people are more familiar with the term Soapbox Racer. Soapbox racing has been around since the early 1900s. The first recorded race was in 1904 in Frankfurt, Germany. Taking inspiration from European motorsport of the era. It was also popular in the United States, so much so in 1933, there was sponsorship by Chevrolet, realising the potential for advertising and large crowds. The Automotive giant created a purpose built track in Akron, Ohio. Which at its most popular, attracted crowds of over 40,000 people (Gravity Coaster, 2019). In more recent years it has experienced a resurgence in popularity by companies such as Red Bull, hosting large, theatrical events. These events have an emphasis on entertainment, with over the top designs and costumes, attracting millions of viewers on YouTube.

This was a group project with various roles, these roles were divided equal among the group and overseen by an elected Team Leader.

This essay will cover the research into the different sections of the vehicle, in order to build the soapbox from scratch. Also, it goes into detail on the costs included and how different budgets were considered, from a shoestring budget to a hypothetical unlimited budget. Lastly, it will show these different concepts and ideas, through hand drawn designs. The Soapbox was designed to compete in Richard's Castle Soapbox Challenge, taking care to adhere to all sporting rules and regulations at every stage of the build.

2 Research

2.1 Bodywork & Design

This section will look at aspects of exterior design, for both safety purposes, aesthetics and what can be done to gain an advantage against the competition. It will briefly cover materials considered, the cost involved, and how practical it is to build.

Soapbox One

The designs for Soapbox One are all conscious of the budget, with attempts to save money on every section of the soapbox. Sticking to a square design to accommodate the types of materials needed, which in this case was a mixture of 4140 steel for the frame, more of which are covered in later sections, for the main frame. Then a mixture of wood and sheet metal for the body. A form of Sheet Metal was concluded upon for ease of fabrication and its strength, the problem faced was which sheet metal would be best suited for Soapbox One. The two options were Mild Carbon Steel and High Carbon Steel. Both have similar characteristics including being more durable than stainless steel. Both types of steel have the negative of not being corrosion resistant (Woodland, 2021). A form of coating would be required on either.

The final decision to go with High Carbon Steel opposed to Mild Carbon Steel was a financial decision due to it being the cheaper option. The fact it is widely used in the manufacture of automotive panels was also a contributing factor.

Soapbox Two

Lightness and ease of manufacture were key factors in deciding which materials would be suitable for the shell of Soapbox Two. Materials considered were Fibreglass and Polyurethane.

The first option considered was Polyurethane. A popular material used within the automotive industry, commonly seen in aftermarket body kits. The fit and finish of Polyurethane is usually made to a higher standard than its Fibreglass equivalent. Making it more durable. When it comes to installation, it can be handled and coaxed into position without fear of cracking. The product has more flex when subjected to a minor impact, meaning it is more likely to flex than to snap and break apart (Zahl, 2015). Ultimately due to Polyurethane being more difficult and costly to produce, in addition to the additional weight different materials needed to be studied.

Fibreglass was the second option to research. Fibreglass had the most history, availability, and information. Fibreglass has been used in car manufacturing since as early as 1939. Then in the 1950s and 1960s, an era of underdog companies appeared by using inexpensive and light Fibreglass moulds, which were easy to mass produce (Classic Motorsports, 2021). Fibreglass is also used in everything from surfboards to glider aircraft, meaning there is a wealth of information on this material, from creating moulds, maintaining fibreglass and how to repair damaged panels.

The main aim for Soapbox Two was weight reduction, the extra weight saving gained from using Fibreglass alongside the fact, it would be cheaper to manufacture met the goals set out when building Soapbox Two, leaving Fibreglass the appropriate material for the Shell.

Soapbox Three

With a high budget, the first material that was considered was CFRP (Carbon Fibre) and Amplitec. Two Materials which are unlikely to be seen on an average road car and more likely to be seen on racing cars and ultra-expensive hypercars.

Looking firstly at the more well known Carbon Fibre, this material is widely used in motor racing and now more commonly in road going sports cars. A material that is stronger and lighter than any steel or aluminium equivalents. This means it has found many uses within the automotive industry. From simple panel replacements to full body shells. When comparing steel to CFRP composites, made with Carbon Fibre, The CFRP will be of equal strength of the steel but weights 1/5TH that of steel. To look

at another light metal such as aluminium, although one of the lightest metals, it would likely weigh 1.5 times as much as the equivalent Carbon Fibre structure (Johnson, 2019). For Soapbox Three, Carbon Fibre combined with an already light space frame chassis would result in a very low yet strong frame, making it a perfect choice.

The Second Material considered is Amplitex, which is relatively new to the automotive industry. This material has an emphasis on being light and strong but also being better for the environment. With claims of up to 75% less CO₂ emissions during manufacture. 16.9kg of CO₂ per square metre for Amplitex, compared to 45.6kg of CO₂ for Carbon Fibre (Crosse, 2020). The costs of Amplitex are also up to 30% lower than Carbon Fibre (Butler, 2020).

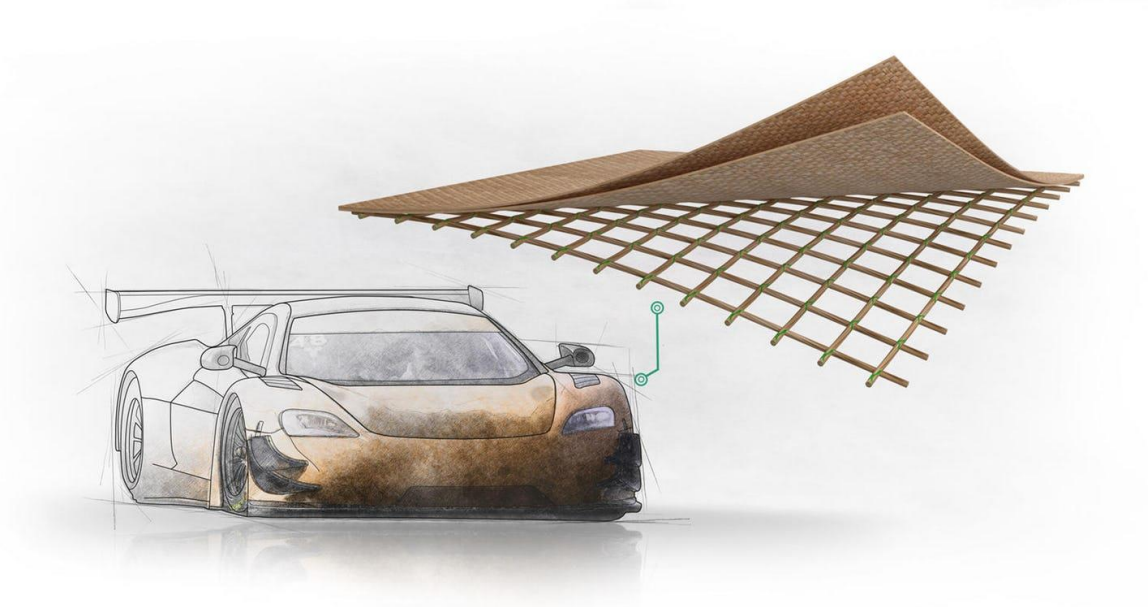


Figure 1 - Bcomp – Amplitex fibre (Crosse, 2020)

To conclude based on the materials researched. Carbon Fibre was chosen to be the best option, with costs not being an issue with Soapbox Three. It comes to which of the materials is more accessible. Carbon Fibre is currently more readily available because Amplitex, for now, is only being made by one company. Leaving Carbon Fibre, which will provide the Soapbox with enough strength while keeping the weight down.

2.2 Chassis

This section will cover the various chassis types that have been considered, researched, and chosen to suit each of the three designs. Key factors are cost, function, and ease of manufacture. It will go into detail on problems faced and how they were overcome to fit each design with the best suited chassis.

Soapbox One

The first chassis type looked at is a ladder frame chassis, also called a box ladder chassis. These are generally made up of two long side-members which are then linked together by cross-members (Hillier et al 2012). Although traditionally it was used on a wide range of vehicles, it is now more commonly seen on utility vehicles and 4x4s. This option was an ideal candidate for a Soapbox racer because it is a strong and cheap method of frame building.

When considering costs, the frame would be made up of simple 2-inch box sections, the cost is going to be lower than the other more complex chassis options, due to both the simplicity of the design and less material is needed. The two types of steel considered were 4130 and 4140. 4140, being the

final choice because 4140 is easier to weld and more readily available (CNCLATHING, 2020). It is more cost-effective in both bar and plate form, both of which will be used in this design.

The nature of construction means the ladder frame is built to absorb impact but the result of this can be poor torsional stiffness, even without suspension.

One way to overcome this is to build a bulkhead, a negative impact could have been the weight of the Soapbox exceeding the 100kg limit as per event rules. The second concern is that the bulkhead is a perfect set up for a roll cage but because tubular steel is not being used, the Soapbox is not required to have a roll cage.

The Second Option that was considered, is to insert an X-brace to increase torsional stiffness. This includes adding an x-member between the two main beams, this design has been shown to give the chassis a stronger torsional rigidity and has been used on Corvette convertibles with a moderate degree of success (Adams, 1993).

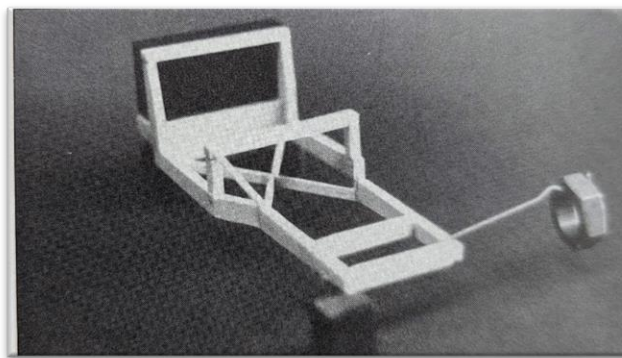


Figure 2 - This photo shows adding an X-Brace does make some improvement in a ladder frame's torsional stiffness. (Adams, 1993, p89)

Another factor in choosing a ladder box chassis was the ease of assembly. It is easier to adjust driving position, wheel layouts and the body shell design because the shape of the frame is constant.

Many famous cars have used the body on frame method of design. Examples include Ferrari's first car, The Ferrari 500 which won every Grand Prix it entered from May 1952 to September 1953 (Formula-1-Dictionary, 2017), through to the utilitarian Land Rover Defender, an incredibly capable off-roader with a production spanning 68 years (Dron, 2016). Providing more than enough evidence that it was a solid and very versatile choice for a soapbox.

Soapbox Two

The second chassis is a backbone chassis. The chassis was invented by the founder of Lotus, Colin Chapman. The chassis is made up of a solid midsection, usually in rectangular sections, connecting the front and rear axle. This section provides most of the mechanical strength of the vehicle and a body is placed on the frame, a material such as a fibreglass is a common choice (Wan, 2000).

A positive of the backbone chassis, with a similar goal to most Soapbox racers, it was built to be light, strong while also being cost effective to make. The backbone has many advantages over a ladder chassis for a Soapbox racer, one of these being less torsional twist than the ladder box chassis (Rangam, 2020) but negatively, when it is compared to the space frame chassis, it is weaker and heavier. Advances in design and materials have resulted in the backbone chassis falling out of favour in production cars (Motoring Weekly, 2018).

Because this type of chassis is still widely used in kit cars, it is possible to buy sections of the frame prefabricated but unfortunately, this is not an option due to the size of the Soapbox back compared to even the smallest kit cars. Although aluminium was considered, the weight saved by using a fibreglass body along with the risk of torsional twist that comes with the backbone chassis, steel was the better option. The type of steel chosen for Soapbox Two is 4140, known for its toughness and high torsional strength (KloeknerMetals, 2021) it helps keep the costs down while having a good balance between weight and strength resulting in the backbone being the perfect middle ground for Soapbox Two.

Soapbox Three

The final chassis type considered is a Space Frame Chassis, sometimes known as a tubular chassis. A space frame is a 3-D structure formed by tubes that are then cladded with non-structural bodywork (Seward, 2014). They are more likely to be seen on track ready road cars and race cars than passenger cars. This chassis type is considered an upgrade from the more basic ladder chassis because it is lighter and stronger resulting in this chassis type being a common sight on race cars along with a handful of high-performance road cars and it is unlikely to be seen on a passenger car.

Soapbox Three is a 3-wheel design with 2 wheels at the front steering the car and a single wheel at the back which will be on a solid axle. While lacking in the ability to design and make a frame from scratch. For Soapbox Three, the style and shape have taken influence from both old and new three-wheel design cars, such as the Morgan 3-wheeler, Campagna T-rex and the Can-Am Spyder.

The main issue with a tubular chassis is the complexity involved with the design. The tubular steel is dependent on measurements being correct and the frame having the correct tubes in the correct places. Another potential issue can be the weld quality during the build, as tubular steel can be more difficult to weld in comparison to the straight lines of the ladder frame chassis. These kinds of issues can lead to weak sections within the frame. The way to overcome this was to keep the design relatively simple for a space frame chassis. One Particular vehicle that aided the design process was the Polaris Slingshot.

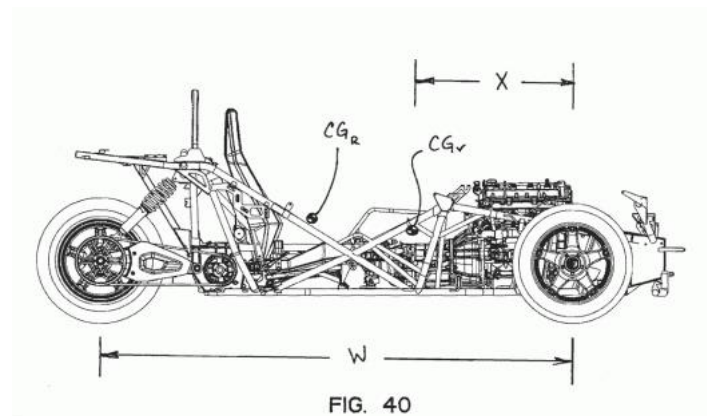


Figure 3 - Polaris 3 wheeler side view without bodywork (Crowe, 2013)

The Polaris design aided the decision to select oval tubing due to its aerodynamic advantage when compared to round or square tubing as it creates less drag. A downside could be that it's not as

structurally strong as square or round tubing when it comes to bending, but for a Gravity Racer, it provides adequate strength (*Build your own race car*, n.d).

The last factor to consider is which steel to use and the costs involved. 1018, 1020 and 4130 grade steel were all considered. Although 1018 and 1020 are considered mild steel, they still carry sufficient strength, 4130 is chromoly grade and is the stronger option of the three. Using a 4130 chromoly grade steel with a thinner wall thickness can also be looked at because it has the advantage of a 35% weight saving over thicker mild steel (Ferrara,2015).

2.3 Steering

This section will investigate the fundamental feature of steering. To determine the perfect steering option for the soapbox design. Multiple aspects will be considered, including the efficiency of steering, the usability, the cost of materials and the difficulty of assembling the design. To maintain the report layout, three different designs at three different price points will be considered.

Soapbox One

The chosen design for Soapbox One has been selected due to its cheap and simplistic nature. The design is called the “Single Pivot and Rope” design. This design uses a simple physics pivot to operate the directional rotation change of the front wheels. All that is needed is a straight beam of metal or wood, to hold the wheels a set distance apart, as well as a length of rope, the length can be based on drivers position from the front wheels. The steering design works by connecting the centre of the metal/wood beam to the frame, tight enough to hold in position but loose enough to allow the beam to rotate. The beam holds a wheel at each end, again loose enough to allow the wheel to rotate, as well as the rope being tied on just along the beam, inside the wheels (Jeff, 2015). The driver is then able to hold the rope, with enough tension to remove any slack, and pull in either direction to rotate the beam and ultimately the wheels around the pivot point. The rope connection between the driver and the beam provides an easy to operate and direct feel. A characteristic of this design means the Soapbox will become unstable and sensitive at higher speeds. (Scottishcartie, 2012) This is not ideal for the final design as the soap box is expected to reach around 30-40mph (Richard Castle Soap Box Derby, 2020). Additionally implementing an easy to operate braking system would be very challenging. However, due to the costing restraints it is the only viable option for Soapbox One.

Soapbox Two

Soapbox Two has an increased budget and allows more steering options to be considered. Soapbox Two will use a more conventional style of steering, the steering wheel. Steering wheels are extremely common amongst automobiles such as cars and trucks. The first ever steering wheel was used in 1894 and was circular in shape. (Autotrainingcentre, 2021) Soapbox Two’s steering wheel will use a yoke style steering wheel made from handlebars from a road pushbike. The handlebars will be rotated 90 degrees vertically to create the yoke steering wheel shape. The use of handlebars creates a foundation already compatible with other manufactured parts. This allows for the braking system to be compatible and easy to use with the handlebars.

Soapbox Two will utilise a “Rack-and-Pinion” system to convert the drivers rotational force into a linear movement. The steering yoke will then be connected to the steering column via an adjustable raiser stem. On the other end of the steering rack will be the Pinion, a circular/ball shaped gear. The rack, in this case a 350mm beam made of metal, with consistently spaced geared teeth along the top edge. Both the Rack-and-Pinions geared teeth mesh together. As the steering column/pinion rotate either clockwise or anti-clockwise, the rack is moved right or left respectively (Muir, 2014). The rack is positioned slightly forward of the front axle and connects to either wheel via the tie rods and steering arms. The tie rods can have their length changed to adjust the alignment and create the

pivot point for the wheels to turn (twconnections, 2007). The minimal usage of moving parts makes the steering system more reliable and precise (Muir, 2014).

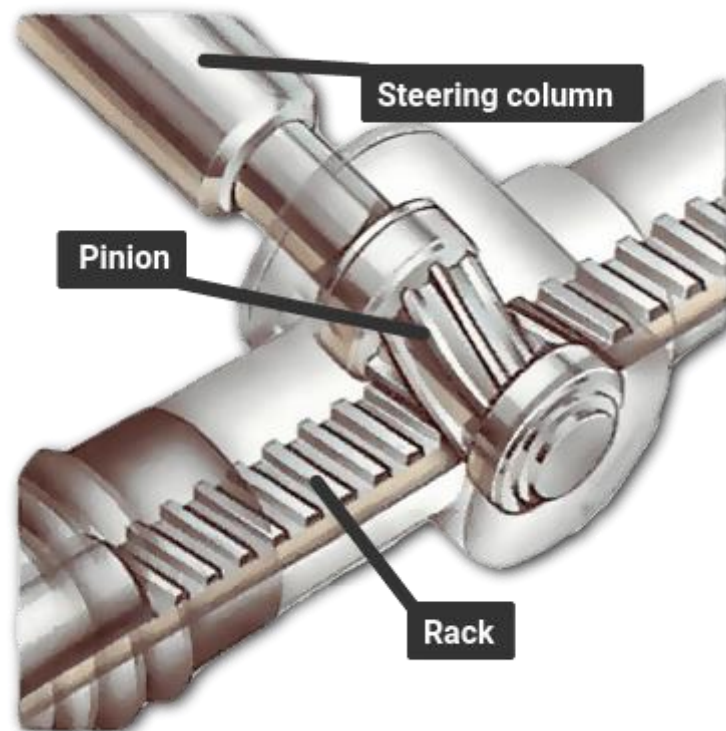


Figure 4 - howacarworks.com - Rack and Pinion Steering

This sophisticated yet simple design allows the system to be applied within the costing restraints. It will require time to test drive the soapbox and make the required adjustments to the handling, however the materials required are accessible and the assembly process will be simple to reciprocate with the correct tools and machinery. This is a very viable option for the midrange costing soapbox.

Soapbox Three

With the unlimited research and development, costing budget for Soapbox Three, the steering system has been developed further to follow closer to the world of automobiles. The first manufactured vehicles used metal with a wood lining to create the wheel. Soon after the wood lining was replaced with plastic as a cheaper, lighter, and safer alternative. Wood lined steering wheels would splinter during accidents, causing additional injury to the driver. More recently leather has been used as lining to provide a premium option for comfort and grip (Volkswagenag, 2021). Soapbox Three will use a 14" diameter metal wheel lined with leather. Additionally, to the steering wheel shape being changed, the Rack-and-Pinion system has been upgraded to provide the driver with a greater steering angle as well as assistance in performing the turns. Soapbox Three will have an electric motor-powered steering assist. The Soapbox will have a small and basic computer system built onboard. Firstly, two sensors will be fitted to the steering column to determine how much force and angle the driver is applying to the steering wheel. Then the electric motor built onto the steering rack will be told by the ECU (Electronic control unit) how much assistance to apply to the linear motion (Michael, 2021). To help with the steering angle, the teeth will widen/spread out on either end of the rack. This increases the ratio of turn and does require more force to push the rack, however the power assist will compensate this for the driver. All the additional components will be fitted around the front axle of the Soapbox to shift the centre of mass forward and increase the front wheel grip. This is a very complex and expensive system, however, is extremely common,

especially more recently in electric powered cars. The circular steering wheel and electric power assisted rack-and-pinion system will be fitted to Soapbox Three.

Additional Research

Soapboxes one, two and three have all been assigned different costing steering designs, however within the research required for this report, a few other options were considered. Additionally, to the rope or steering wheel design, the consideration of other driver inputs was discussed. Some simple, just like flat pushbike handlebars, and some quite sophisticated designs like the electric computer powered joystick used in the Saab 9000 Prototype back in the early 90's. (Axon, 2018) More so the conversion of input to the front wheels, like the recirculating ball steering design used more so in trucks and larger vehicles. (Karim, 2021) The addition of these ideas to the Soapboxes was voted upon whether to continue to develop these into the final designs.

2.4 Brakes & Wheels

Brakes and wheels are arguably the two most important components when designing and creating a soapbox. This section will be looking at the advantages and disadvantages of each wheel design and brake design for each Soapbox design. The brakes have been selected for their practicality and affordability. The wheels and tyres have also been selected for their affordability, practicality, grip and strength.

Soapbox One

Brakes

The first design for the brakes is going to consist of rubber and wood to create our brake. The brake is going to be created through a lever and rope design which will then push two blocks of wood with rubber attached to the ends to push against the wheels and create our brake force. This will be by far the cheapest option for the soapbox as the materials will be at most £5. Research into using metal in place of the wood was also completed but this would increase the prices drastically and would be in the price region of the other design which provides more brake force leaving this design futile. This design would also require the driver to take their hand off the steering wheel to use the lever which could put them in unnecessary danger compared to the other designs as the driver will be restricted in controlling the movement of the steering wheel.

Wheels

The first design for the wheels and tyres is based on a bicycle tyre and wheel. It is found that the soapbox track plays a big part in tyre selection. A major concern with a limited budget would be the wheels not having enough strength and integrity to survive the track and the number of runs needed. The lack of quality for this price point might hinder the soapbox but if the budget was increased it would not meet the budget criteria for this price range. The more corners and braking needed would need larger wheels and tyres. This will increase grip and would mean the driver can brake later and corner later than they would be able to with thinner wheels and tyres. Soapbox one is built with a lower budget in mind. The most reliable size wheel would be around 16 inches, this is commonly found on a children's bicycle. This would be the perfect fit for soapbox one as they excel in taking corners at high speeds due to their low ground clearance (Scottishcarties, 2013). They will also be able to withstand the cornering weight of the soapbox and driver. This is also very cost effective as they are very common parts and easily accessible.

Soapbox 2

Brakes

The second brake design will consist of a traditional bicycle V brake set up. This provides a greater stopping distance than the Soapbox One. Making it more efficient for the course layout. As a different budget was agreed upon for each design, this set up is in the middle range of the three

different soapbox designs. As Soapbox One had its issues regarding safety and practicality in the deployment of the brake, this design would allow the driver to use the handlebars as well as the traditional handlebar and brake design more commonly seen on a standard bicycle and would not impair the driver in terms of steering. Another option explored for this would be a custom fit foot brake instead of the standard bicycle and handlebar combination. This would provide greater stopping distance but would be more time consuming as we would need to design and make the components ourselves. This may also impair the driver as it is far less common, and the driver would need to familiarise themselves with an entirely new system. This left this idea obsolete and would not be beneficial for the small increase in stopping power. The installation could be straightforward as all the components needed are commonly available. The only issue found is that mud and water are likely to affect the brakes significantly. The V brakes would need to be thoroughly cleaned between each run. This may not seem like a big issue but if there is more significant damage that needs to be addressed this process may be forgotten about.

Wheels

This design would be nearly identical to the design found in soapbox one for the wheels and tyre design. This is necessary as the V brakes will need to fit safely onto the wheel and tyre. The only difference would be a change in quality. As this is the middle range choice. This design would consist of 27.5 inch wheels and tyres. More specifically hybrid road tyres. Through this upgrade, we can improve the tyre quality subsequently increase grip as they will have a certain tread on them that would improve the off-road quality as well as maintain the on-road quality (Tredz , 2022). Increased manoeuvrability, cornering at high speeds and tyre wear. The tyre would also be able to withstand the pressure put upon it by the V brakes which is the main factor in pairing these two designs together.

Soapbox 3

Brakes

Design three is going to be created through a disc brake design which is common on bicycle tyres. This design has the greatest stopping distance out of the three designs, but it is also the most expensive. This would enable our soapbox to be more consistent, more reliable and would need far less servicing than either of the other two options. The installation would be straightforward as we have decided on a system that includes the use of hydraulic braking. The application of the brakes would be through paddles on the back of the steering wheel. This would be beneficial to the driver as they do not need to take their hands off the steering wheel. This ensures the safety of the driver. This is more expensive than mechanical disc brakes, but the benefits are far greater. This includes a closed hydraulic system which means the mud and debris would not be able to enter the brake lines, which also means it is far safer. This system also means the driver of the soapbox would not need to press any harder for more stopping power as the hydraulics will do the work for them (Tony, 2021).

Wheels

The third design is going to consist of 700c carbon wheels and tyres. This is the most expensive option out of the designs. The carbon fibre makes these wheels extremely lightweight but also, they can withstand the cornering speeds and weight of the soapbox and driver. The tyres also offer a far greater quality which means the grip is improved, manoeuvrability, cornering and tyre wear. They are excellent tyres and wheels on the road, but the off-road section of the soapbox event may hinder and hold back their full potential.

3 Final Design

3.1 Summary of Design

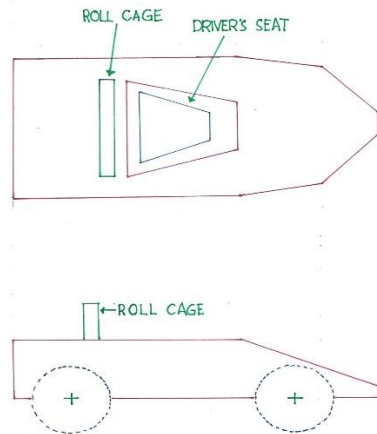


Figure 5 - Soapbox Two – Exterior Design

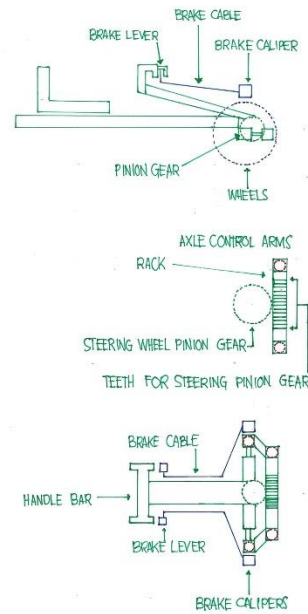


Figure 6 – Soapbox Two – Technical Details

This final design agreed on, consisted of a bodyshell design made from fibreglass, positioned on top of a backbone style chassis made from 4140 steel, welded together with a MIG welder. The roll bar and handguards are also MIG welded onto the chassis but will be made from galvanised steel. The roll cage will be positioned 35mm above the driver's head and handguards 25mm past the driver's hands, all to comply with the rules of the competition. The braking system uses a bicycle style rim-brake set up, over both sides of the axle, connected to 27.5" bicycle wheels wrapped in hybrid tyres. These will help to minimise rolling resistance while not sacrificing grip which is needed for the off-road section of the course. These choices also continue with the lightweight approach to the build. The steering uses a yoke style system, which is built from bicycle handlebars that have been rotated 90 degrees. This also allowed Soapbox Two to use a rack-and-pinion system, the most conventional steering system, aiding the ease of the build by being compatible with many other manufacturers parts.

The entire build will weigh around 78kg before the addition of the driver. The Soapbox will be 1200mm long, 800mm wide and the height is 1506mm. It will sit at 300mm above ground to comply with regulations and to easily cover the offroad section of the track.

3.2 Materials and Pricing

Material Costs

Bodywork fiberglass total square footage 18.27ft - £365.40 (Grlite, 2022)

4140 mild steel 2x1 inch box section 2.2m - £46.50 (Amazon, 2022)

Driver seat - £40 (eBay, 2022)

350mm of steel gearing costing - £13.30 (eBay, 2022)

Pinion gear to fit our 1.5mm spacings - £20 (eBay, 2022)

Steering column bracket - £33.50 (eBay, 2022)

27.5" rim brake wheels - £65 (E-VENTUREBIKES, 2022)

Rim lock brakes - £15 (Amazon, 2022)

Carbon fibre road bike bull bars - £35 (eBay, 2022)

Brake cable 2m - £5 (Amazon, 2022)

Axel control arm £20 (buycarparts, 2022)

Roll cage - Galvanised - £8 (themetallstore, 2022)

4 Conclusion

To conclude, the research undertaken covered a broad spectrum of different methods in which to approach this project. Care was taken to cover all available options for each budget, while also looking at more common materials alongside more expensive materials which may otherwise only be found in motorsport.

After voting at each stage of research and design, a unanimous decision was to go with Soapbox Two, with all details put together this aided the decision to go with a solid, lightweight design that would make for a competitive Soapbox. Taking into account, the rules and regulations in place, a plan was put together to build a lightweight body on top of a solid chassis while incorporating an easy to build steering system along with reliable and robust brakes. The Soapbox manages to be built within a reasonable budget while being under the limit of 100kg.

Going forward, suggested modifications to the Soapbox could include different wheel and tyre set up, switching to a more aerodynamic shell to gain a competitive edge, or changing to one of the alternative materials researched, which have been covered in this essay, such as carbon fibre.

5 Further Study

Due to the nature of the project and the depth of information available, technical limitations were a stumbling block from the earliest stages of design. This section will cover this in more detail, and what would be done differently if the project was undertaken again.

Early into the project, the lack of technical ability with Computer Aided Design (CAD) became apparent, as hand drawn sketches became inaccurate and unable to match exactly what was expected from the design brief. The use of CAD could also have been used to find out the strengths of various materials and set up, avoiding a trial and error process when it comes to the build. One design that would have benefited from using CAD was Soapbox Three with its Space Frame Chassis. A restriction through the project was budget and time. Although an unrestricted theoretical budget was used for Soapbox Three, it would be unrealistic to make, so less time was taken into some of the methods and materials included in the build, due to the knowledge that it was unlikely to ever become a realistic option because of budget. The downside to this is less research into newer more exotic materials and more exciting aerodynamic designs.

If the project was to be approached a second time, the areas of research that could be explored include aerodynamics and suspension. Two areas that were avoided, suspension being avoided due to group size and time. Aerodynamics being avoided because the time and research needed to find out if it was beneficial at low speeds would have simply taken too much time and use of software in which there was no access.

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7 Appendix

7.1 Gant Chart

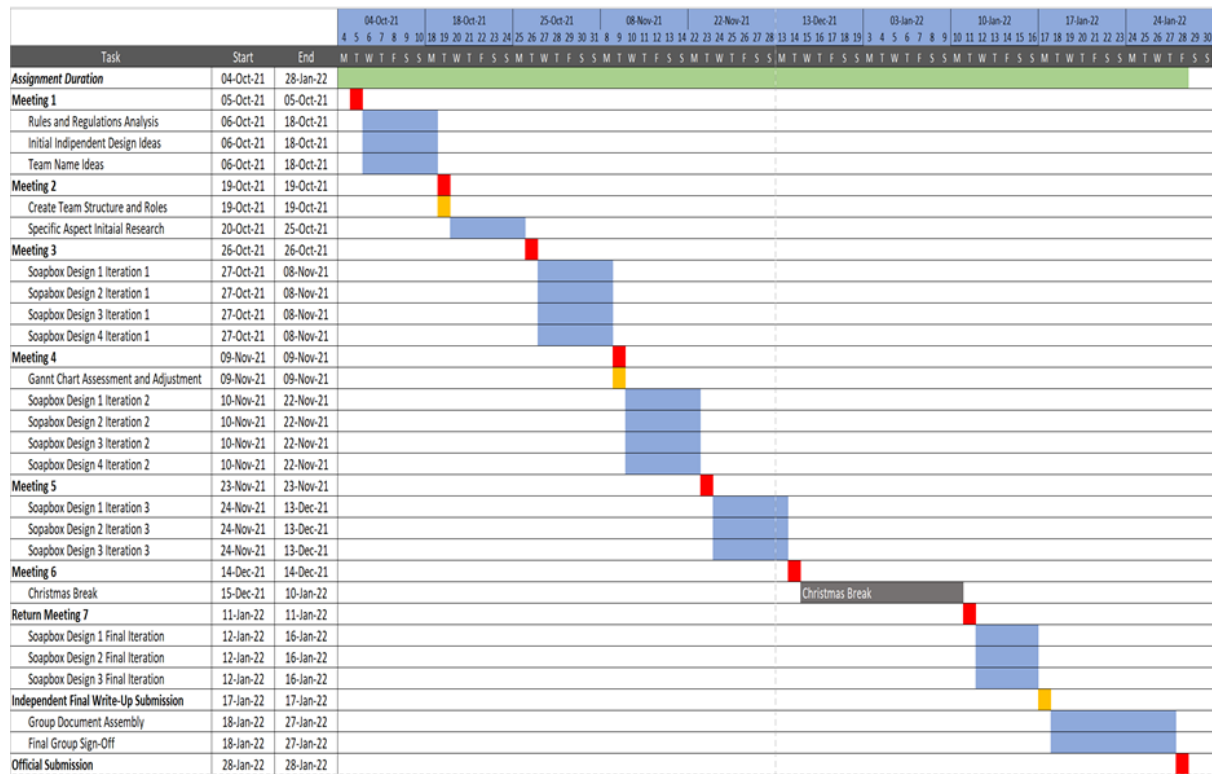


Figure 7 - Gantt Chart

7.2 Meeting Minutes

LMJ3 Integrated Project Meeting Minutes

5th October 2021

Group Meeting 1

Attendees: Luke Dyas, Michael Carlo, Joshua Thomas, Jimmy Vine, Joshua Davies

- 15:15 Luke Dyas calls meeting to order
- 15:16 Each team member introduces themselves
- 15:25 Luke Dyas discusses meeting plan with team
- 15:28 Team has a general discussion of ideas and plan for the team dynamic
- 15:40 The decision is made for each member to read through rules and regulations in their own time and come up with at least 1 design each to bring to discussion in the next meeting.
- 15:42 The team discusses team names. Each Team Member is required to provide a team name in the next meeting.
- 15:50 The team discusses any previous Gantt Chart knowledge. The decision has been made to plan and start the Gantt Chart after next meeting.
- 16:00 The team aims to organise a meeting every 2 weeks, on a Tuesday for group availability.
- 16:10 Jimmy Vine goes over what each member is required to do for the next meeting
- Any Team names
 - Research Gantt Charts
 - Read over rules and regulations
 - Read through Assignment Specification in more detail
 - Remember to reference any additional research

- 16:15 Next meeting agreed on 19th October 2021
16:16 Luke Dyas asks A.O.B
16:17 Meeting ends

LMJ3 Integrated Project Meeting Minutes
19th October 2021
Group Meeting 2

Attendees: Luke Dyas, Michael Carlo, Joshua Thomas, Jimmy Vine, Joshua Davies

- 10:05 Josh Davies calls meeting to order
10:06 Josh Davies discusses points from previous meeting and asks all members to agree to meeting minutes.
10:08 Meeting Minutes pass (5-0-0) (**In favour – Opposed – Abstentions**)
10:10 Luke Dyas introduces the next point of coming up with a team name
10:11 Michael Carlo suggests RevLine Team
Notion Opposed (1-3-1)
10:14 Joshua Thomas suggests team name should be linked to the “Group B Rally Cars”
Notion Opposed (2-3-0)
10:17 Jimmy Vine suggests team name “LMJ3”
Notion Passes (5-0-0)
10:20 Jimmy Vine leads discussion in team structure and roles.
Team structure and roles are as follows:
Team Leader/Steering Design: Luke Dyas
Body Design: Michael Carlo
Chassis Design: Jimmy Vine
Braking and Wheels: Joshua Thomas
Materials and Costing: Joshua Davies
Notion Passes (5-0-0)
10:40 Each member agrees to complete initial research in their assigned aspect.
10:42 Luke Dyas discusses rules and regulations key points with team.
10:52 Luke Dyas discusses assignment specification key points with team.
11:00 Luke Dyas volunteers himself to do Gantt Chart ready for next meeting.
Notion Passes (5-0-0)
11:05 Luke Dyas volunteers to complete all team meeting minutes.
Notion Passes (5-0-0)
11:10 Next Meeting agreed on 26th October 2021
11:11 Luke Dyas asks A.O.B
11:12 Meeting ends.

LMJ3 Integrated Project Meeting Minutes
26th October 2021
Group Meeting 3

Attendees: Luke Dyas, Michael Carlo, Joshua Thomas, Jimmy Vine, Joshua Davies

- 12:05 Luke Dyas calls meeting to orders
12:06 Luke Dyas discusses points from previous meeting. All meeting members are asked to read and agree to meeting minutes.
12:10 Meeting minutes pass (5-0-0) (**In favour – Opposed – Abstentions**)
12:12 The team discusses a variety of soapboxes

- 13:00 Team agrees on following 4 main Soapbox designs.
Soapbox 1: Cheap box shape 4-wheel Soapbox
Soapbox 2: Realistically priced 4-wheel Soapbox
Soapbox 3: 3-wheel with 2 front wheels
Soapbox 4: 3-wheel with 2 rear wheels
13:05 Luke Dyas presents Gantt Chart Plan – from 4th October until 30th January 2022 – including Christmas break
Notion Passes (5-0-0)
13:10 Next meeting agreed on 9th November 2021. All members will continue in depth research for each design.
13:15 Luke Dyas asks A.O.B
13:16 Meeting ends.

LMJ3 Integrated Project Meeting Minutes
9th November 2021
Group Meeting 4

Attendees: Luke Dyas, Michael Carlo, Joshua Thomas, Jimmy Vine, Joshua Davies

- 13:00 Luke Dyas calls meeting to order
13:06 Luke Dyas discusses points from previous meeting. All meeting members are asked to read and agree to meeting minutes.
13:10 Meeting minutes pass (5-0-0) **(In favour – Opposed – Abstentions)**
13:12 Michael Carlo and Jimmy Vine present initial research and designs for body and chassis.
13:30 Joshua Thomas presents initial research and design for braking and wheels
13:30 Luke Dyas presents initial research and design for steering
13:40 Joshua Davies presents initial research for Soapbox materials
13:50 Luke Dyas makes minor amendments to future Gantt Chart plan based on current expectations.
14:00 Next Meeting agreed on 23rd November 2021.
14:05 Luke Dyas asks A.O.B
14:06 All members agree to continue research across the 4 initial Soapbox designs.
14:08 Meeting ends.

LMJ3 Integrated Project Meeting Minutes
23rd November 2021
Group Meeting 5

Attendees: Luke Dyas, Michael Carlo, Joshua Thomas, Jimmy Vine, Joshua Davies

- 12:04 Luke Dyas calls meeting to order
12:06 Luke Dyas discusses points from previous meeting. All meeting members are asked to read and agree to meeting minutes.
12:10 Meeting minutes pass (5-0-0) **(In favour – Opposed – Abstentions)**
12:13 Jimmy Vine and Michael Carlo present developed research for body and chassis designs.
12:25 Luke Dyas presents developed research for steering designs.
12:35 Joshua Thomas Presents developed research for braking and wheels.
12:45 Joshua Davies presents developed research for potential Soapbox materials.
12:55 A group discussion regarding the 4 Soapbox designs leads to the vote of reducing the report to 3 final Soapbox designs.
13:10 Vote to complete 3 final designs as opposed to 4.

Notion Passes (5-0-0)

13:15 Next Meeting agreed on 14th December 2021

13:20 Luke Dyas asks A.O.B

13:21 Meeting ends.

LMJ3 Integrated Project Meeting Minutes

14th December 2021

Group Meeting 6

Attendees: Luke Dyas, Michael Carlo, Joshua Thomas, Jimmy Vine, Joshua Davies

16:00 Luke Dyas calls meeting to order

16:03 Luke Dyas discusses points from previous meeting. All meeting members are asked to read and agree to meeting minutes.

16:05 Meeting minutes pass (5-0-0) **(In favour – Opposed – Abstentions)**

16:10 Quick discussion on how everyone is feeling and getting on with research.

16:30 Last discussion before Christmas break

16:40 Next Meeting agreed on 11th January 2022

16:45 Meeting ends.

LMJ3 Integrated Project Meeting Minutes

11th January 2022

Group Meeting 7

Attendees: Luke Dyas, Michael Carlo, Joshua Thomas, Jimmy Vine, Joshua Davies

10:00 Luke Dyas calls meeting to order

10:03 Luke Dyas discusses points from previous meeting. All meeting members are asked to read and agree to meeting minutes.

10:05 Meeting minutes pass (5-0-0) **(In favour – Opposed – Abstentions)**

10:08 Team regroups after Christmas

10:20 Team assesses and continues with Gantt Chart plan

10:30 All members agree to submit a write up of all their research by the 17th of January 2022

Notion Passes (5-0-0)

10:35 All members agree to meet for final write up sign-off on the 27th January 2022

Notion Passes (5-0-0)

10:40 Jimmy Vine, Joshua Davies, and Luke Dyas volunteer to complete final submission document

Notion Passes (5-0-0)

10:45 Luke Days asks A.O.B

10:49 Meeting ends

LMJ3 Integrated Project Meeting Minutes
27th January 2022
Group Meeting 8

Attendees: Luke Dyas, Michael Carlo, Joshua Thomas, Jimmy Vine, Joshua Davies

- 17:00 Luke Dyas calls meeting to order
17:05 Luke Dyas discusses points from previous meeting. All meeting members are asked to read and agree to meeting minutes.
17:10 Meeting minutes pass (5-0-0) **(In favour – Opposed – Abstentions)**
17:15 All member read through final document and agree for Jimmy Vine to complete submission on the 28th of January 2022
17:45 Notion Passes (5-0-0)
17:50 Meeting ends.

7.3 Designs

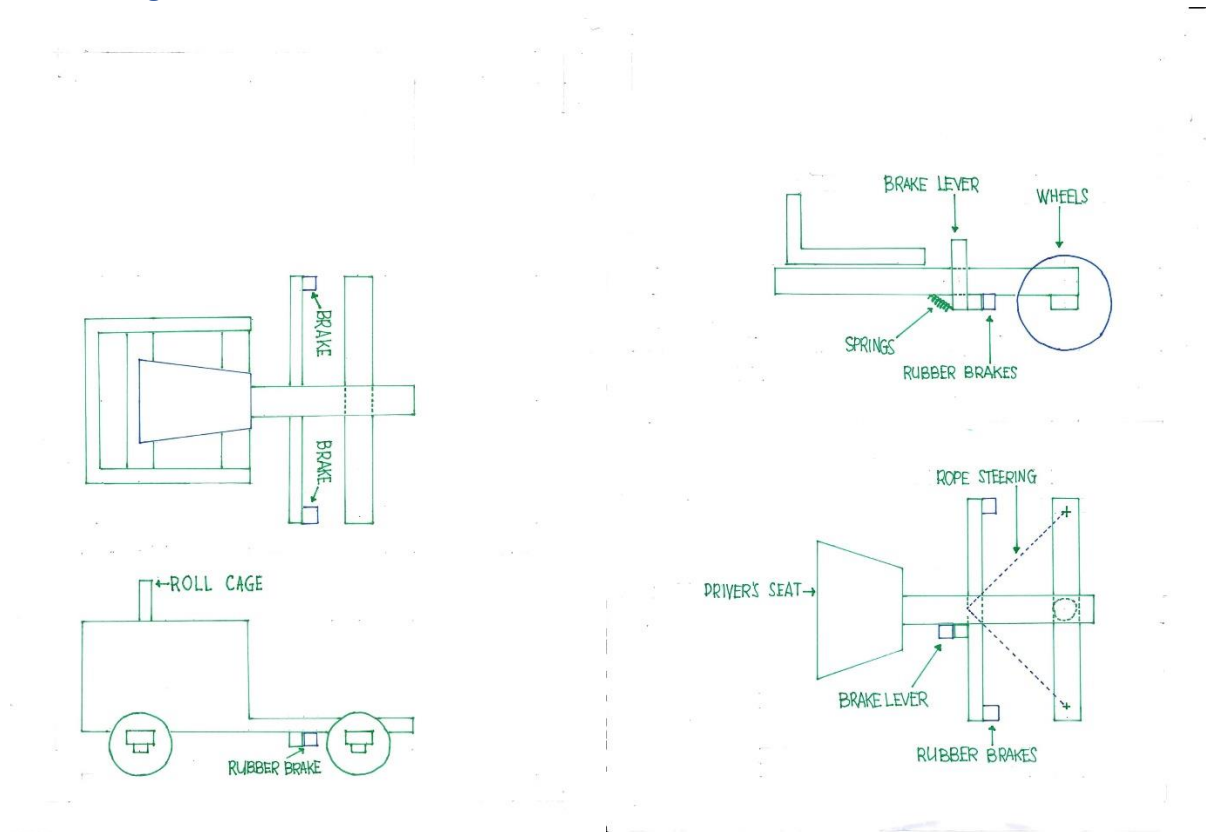


Figure 8 - Soapbox One - First Draft

Figure 9 – Soapbox Two – Technical Details

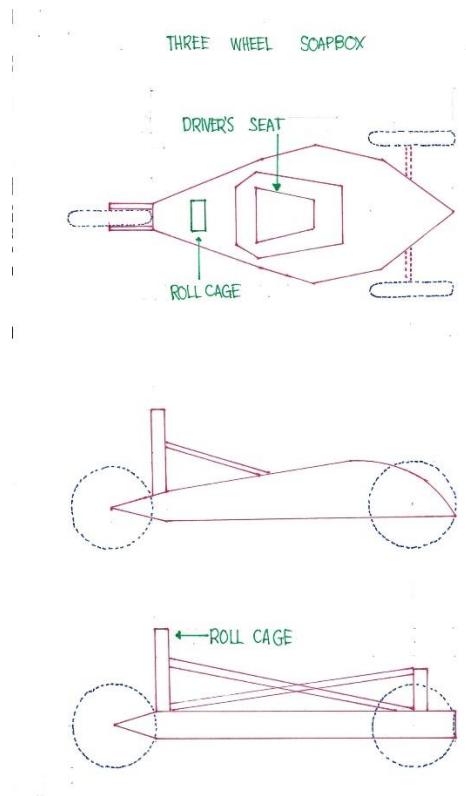


Figure 10 - Soapbox Three - First Design

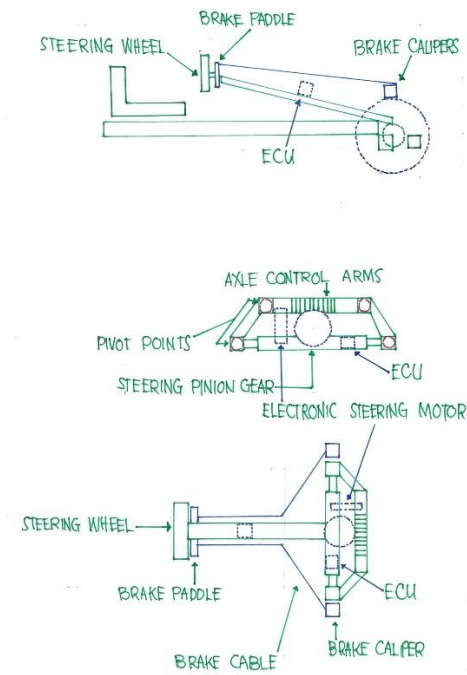


Figure 11 – Soapbox Three – Technical Details