MD27 - Bike Project Report

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Interim Presentation Report

At the time of the interim presentation we had done almost everything that we had planned on doing for the presentation. This included research into the target market and target users, gantt chart, house of quality and initial sketches and CAD.

In this section of our report we want to go through what we gained from the interim presentation and how that experience changed our approach towards the project. This is both from watching other presentations and listening to their feedback and from our own presentation and the feedback we received.

What we learnt

- Morphological Analysis

The Morphological analysis was a talking point in the feedback section for all groups, not just ours. The overall opinion was that the morphological analysis was too generic and focused more on non-specific bike design options, e.g. aspects that could affect any bike design instead of aspects aimed towards each group's specific briefs. There were also comments that more knockon choices were wanted. This is where choosing option 1 for the first row would impact what choices you were able to take in later rows.

Our morphological analysis included too many unnecessary features that were of no importance to the bike design itself. Only one route was taken down our morphological analysis which resulted in only one design whereas if we had explored different routes we would have multiple design options where we can compare them to see which is better.

- CAD

The CAD we had in the presentation was initial models to help visualise our concepts through the modelling medium instead of sketches. To this extent they did what they were meant to but we learnt from the feedback that for our final CAD model they would have to be more sophisticated models. From these models we would then be able to show more precisely the representation of the bike and would be able to run simulations on the pieces.

- House of Quality

The house of quality was unfinished at the time of presenting but contained the main body of the table. Although the main body of the table has been kept mostly the same since the presentation, from watching other groups present and observing the house of Qualities that they had made we were able to pick out points we had missed but we thought were important to include. From this we expanded our house of quality to include these new factors.

- Gantt Chart

    The initial gantt chart, although appropriate at the start of the problem, needed to be altered due to new aspects of the design process we previously had not considered. So plans to produce a new one were already in the works before the interim presentation. The feedback on the initial gantt chart overall was positive with the contents being praised and only commenting on the slight messiness of the appearance. Due to some words being cut by the size of columns and such other small aesthetic details. These would be changed in the next iteration of the gantt chart.

- Presentation Design

    Through watching the presentations and discussing each one within our group we came to the conclusion that the powerpoints that utilised open space to ensure a clean and professional slide appearance were our favourite. After looking back at our slides and hearing the feedback from the lecturers we realised that our slides were a little bit cluttered and due to that seemed unprofessional and hard to follow at points.

- Time Management

    Before the official presentation of the interim presentations we had several run throughs to check, adjust and check again our timing and if it came under the 7 minute allotted time. This ensured that when during the presentation we came in under the 7 minute mark but were able to utilise our time to the fullest as well.

What we improved

We addressed every part of our presentation in preparation for the final presentation but the specifics are as follows :-

- Morphological analysis

  Created a new morphological analysis with components that were more specific to our bike design and included knock on features in it too such as backrest configuration and backrest material where some options limited the following available options.

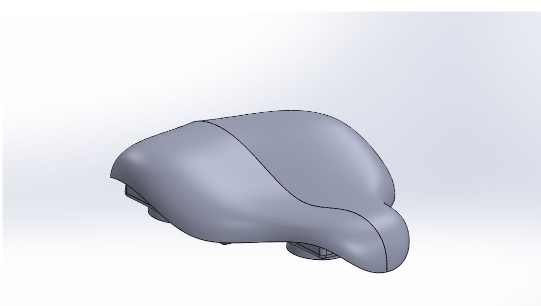
  Multiple routes were taken down this new morphological analysis table to result in differing design and widening our range of thoughts for possible final concepts.

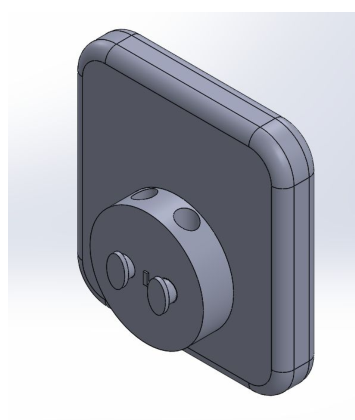
- CAD

Our CAD models that were created before the interim presentation were unplanned and rushed, these included a badly drawn seat, backrest and handlebars.

After the interim presentation the quality of our CAD work was deemed unacceptable and we went back to the drawing board and started from scratch. We realised that more planning and research was needed before designing the parts of our bike on Solidworks.

We completely changed the design of all our parts, our bike seat was completely changed from a cruiser bike seat to a noseless bike seat as from extended research it was realised that this was more beneficial and adhered more to our user requirements for the most comfortable ride. Images of our initial designs for the seat and backrest can be seen below.





Rendered images of our final designs can be seen throughout the report and it can be seen that, in comparison, they are massively improved and much more intricate. Our designs were also better planned out and not rushed.

- House of Quality

The house of quality was edited, adding in the new features, and then finished comparing it to two existing dutch style upright bikes for men. This helped us get more of a grasp of existing products and solutions already in place for problems we may encounter.

- Gantt Chart

New tasks and subtasks added to more accurately represent areas that needed to be completed within the design of the bike as the original Gant chart had nowhere near enough detail from proper time keeping, an image of our original Gant chart is in the Gant chart section. Allocation of tasks reevaluated to suit each individual's strengths.

Why was it useful

The interim presentation and feedback was useful to the project as it helped to identify weak areas of our project and how we would be able to improve them with small or large changes. We all agreed that what we thought the most useful part in helping us identify where we could improve was not in fact our own presentation and feedback but observing other groups. We had at least two of our group members sit in for the entire week of presentation where they would take notes and ultimately relay their notes and thoughts back to the rest of the group. This not only helped with the presenting of our own project but we were able to pick out things other groups were doing well that we hadn't thought of and adopt it into our work. This included things from stylising the powerpoint all the way to more accurate group meeting minutes.

After the interim presentations our group absorbed all of this advice and new information to improve not only our project but our working environment.

Overview

The following is a report made during the ENG2016 Mechanical Design course. Teams of five students from various engineering disciplines were challenged with designing bikes for specific briefs and tasked with completing all stages of the engineering design process to result in a final product with detailed analysis of steps taken and the results reached. The following is group MD27’s project report.

Project Brief

The project brief we chose had three main components:

- Dutch Style Bicycle

Dutch style bicycles are ridden in the upright riding position and generally only used on paved surfaces or well formed paths. Due to the location they are mostly used in, the bicycle is not designed for severe inclines or mountain climbing.

- Males aged 55+

When considering a male target market of over 55 years of age we will have to take into account the average weight of males, the potential limited fitness of the aging population and aim it more towards recreational or regular commuting purposes.

- With Back Pain

With back pain can come many side effects, the main one affecting our bicycle design being mobility. Reduced reach, flexibility and movement as a result of back pain will narrow possible design features. To make the ride quality comfortable enough for back pain extra support may also be required to make the product usable.

Goals

1. To function as a group as if in a realistic working environment
2. To create a bike design that is both functionally and conceptually appropriate for our brief
3. To come out of this project having developed not only a product but transferable skills.

Gantt Chart

Gantt charts are used as a progress versus time comparison, which is useful in ensuring that the project group and the individuals it is composed of keeps on top of activities and runs on schedule. Due to this we made a gantt chart to track our progress and remain proactive with regards to deadlines, just as it would be completed in industry from conception to final assembly.

We started by identifying the main sections needing inclusion in the chart, for example desired characteristics, dimensioning (as shown in the task column of the chart below) etc. Each of these tasks or sections were key parts to be completed in the design process so must be included. These tasks could then be split into sub tasks to handle the more specifics or quite generic main tasks. These sub tasks also allowed us to assign group members to specific tasks to ensure that all would be getting work done on time.

Original Gantt Chart

The original gantt chart constructed by Finlay but with input from the entire group is shown below. As shown below, the colours correspond to which group member would be taking lead in that task or if the whole group would work together to complete it.

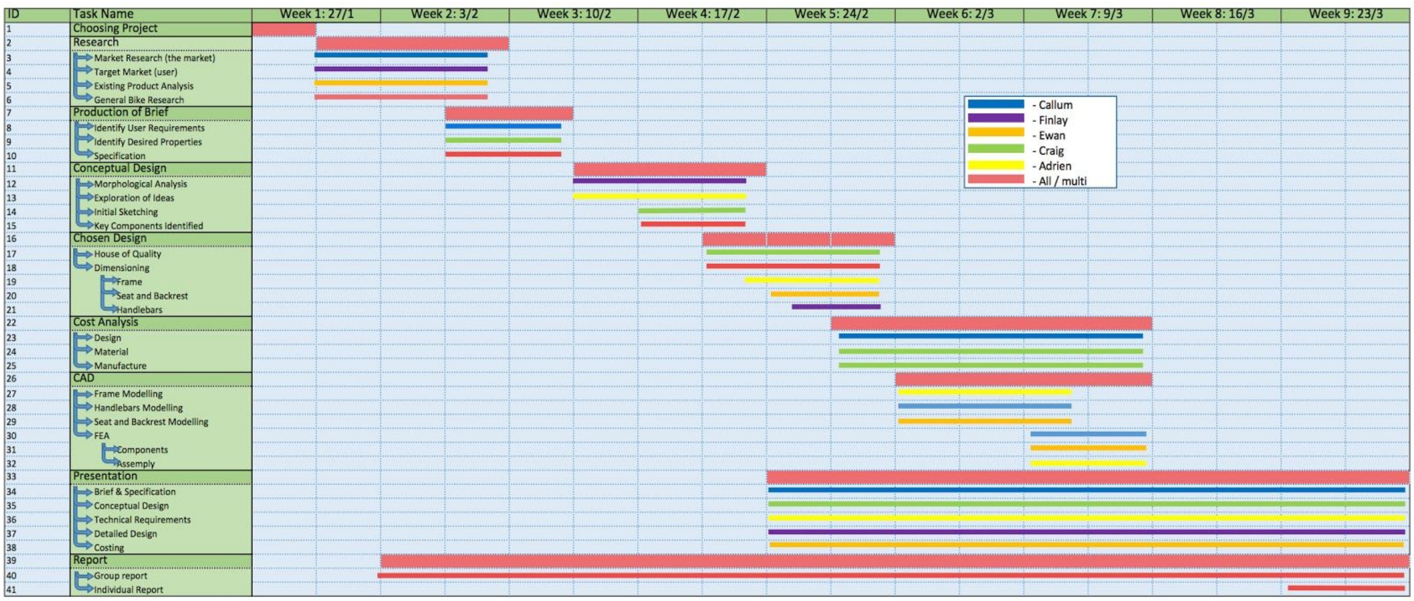
The first task is “Desired Characteristics” which includes the sub-tasks “Main Characteristics”, ”User needs” and “Specific Requirements”. As these are initial tasks that alter the direction of design taken we decided to explore all of these as a group to fully understand and agree upon the first step decisions we were making. This ensured everybody was satisfied with the direction the project was going.

After the initial whole group part, we each took specific areas to work on that played into our individual strengths aiming to maintain a high standard throughout. This type of style was applied to the rest of the gantt chart too allowing for an even workload among members of the team.

The big internal projects such as the interim presentation, report and final presentation were not pinned on individual members but instead were spread amongst the entire team to ensure equal input to the important sections of the project

Revised Gantt Chart

After the interim presentation we had to have a look back and evaluate how far we had come and how far we still had to go. While doing this we were able to expand a lot of previously unknown categories as we had learned what was needed to complete them to a high standard. Below is the revised gantt chart that was made during week 4 of the project.



The revised gantt chart has expanded and introduced previously unrecognised areas of the project that needed completion and has offered more space for assigning individual or group work. Each member of the group has their own colour which is used to assign them to specific tasks but the colour red is also used to indicate when multiple group members are working on said activity be it two group members or the entire team.

As the new gantt chart was being started off at week 4, the main focus of interest is in the weeks after that. The “Chosen design”, “CAD” and “Presentation” were the most vastly improved sections since the initial gantt chart as we now knew what went into making these sections. Within the “Chosen design” section we allocated the three main components that made our bike different to other bikes to three individual team members so that they could focus on their part putting all their time into making it to the highest standard. While the two remaining group members worked the house of quality and other less unique jobs but none the less important jobs.

Into the CAD section, we decided it was best to keep the same people working on the same components, as they knew the most about the part they had been working on. Having three people working on CAD at the same time was efficient but required good communication between them as the parts needed to be fitted together once each individual component was completed and therefore their dimensions and joining mechanism needed to be planned out and adhered.

We had decided to work on the report throughout the entire project by keeping documents of individual sections that were then easy to insert into a larger layout. Having the project worked on the entire project allowed it to evolve as the project and design did, resulting in a higher quality report.

With the presentation being scrapped due to the covid-19 outbreak we were set to remove that section from the gantt chart but as those sub tasks also apply to the report we decided to leave them in but combine them with the Report section. This allowed for more accurate spread of work for the report to be monitored and maintained.

Specification

The following Product Design Specification has been made to highlight criteria that would be important to include in the main brief while designing this Upright Bicycle aimed at men aged 55+ with back pain. The PDS covers sections such as performance, environmental factors, safety and other primary sections.

The criteria are ranked from 1 to 5 on how important they are to consider. 1 being the most important and 4 being the least important.

Aspect	Criteria	Rank of Importance (1-4)
Performance	The Bicycle must be large enough to fit an adult male 95%ile in size and yet small enough so that 5%ile of size still finds it comfortable.	1
Performance	Must promote a more physically relieving posture position of the user	1
Performance	Must be able to support a load of 130kg and still be fully functional.	1
Performance	Must provide a smooth ride over paved terrain/minor potholes to ensure the comfort of the user.	1

Performance	Must be comfortable to ride and put minimal strain on the users back as the user can be on it for a long period of time.	1
Performance	Must operate with reasonable effectiveness in all weather conditions such as rain, snow and ice.	2
Safety	Must be able to be slowed down in a smooth and controlled manner ensuring the safety of the user.	1
Longevity	Must be designed so that all the main components will be in working order for either 10 years or 10,000km of use depending which comes first	3
Longevity	Must be made of durable material or have a surface finish such that it will not be affected by corrosion from moisture or chemicals in the outdoor environment for 15 years	3
Longevity	Vibrations caused by bumps and rough underwheel conditions should not affect the structure or integrity of the bike	2
Manufacture	Components must be secured safely and tightly without risk of falling apart.	1
Maintenance	Parts that need replaced if broken should be readily available and should be replaceable by a trained technician or a bike repair shop over the period of a day or two	3
Testing	Testing should be done on a certain amount of products, say 1 in 20, to ensure a high quality assurance is kept	2

The PDS includes the important factors to consider when designing our bike and thus we will refer to it during our processes to ensure that the bike meets our initially set out requirements.

Current Market Analysis

General Benefits

For anyone suffering from back pain, cycling is an ideal way to stay active while keeping strain on the back to a minimum. Due to cycling being a non-weight bearing and low impact activity, it is considerably less strenuous and jarring than other types of exercise such as jogging or aerobics. It also has several aspects which are extremely beneficial to someone who suffers from back pain. For example, regular cycling can help enhance strength, balance and coordination while also improving flexibility and joint mobility. On top of this, another important factor is that with a well-fitting bike, cycling can promote improved posture – something which is highly important to those who suffer from back pain.

Target Market

Although initially the brief may seem quite specific, there is actually quite a large number of potential consumers of our product. In the UK alone, statistics show that there are roughly 10 million men aged 55+ with around 80% of them having reported to suffer from back pain at some point or another, making for a huge number of possible buyers. Also, this number is on the rise as a growing number of people are attempting to lead healthier and more active lifestyles. As for the user, both our conceptual and final designs are created around the average dimensions of a man aged 55+, taking into account arm, leg and back length.

Market and Existing Products

In terms of the current market for bikes of a similar design to our own, prices can range quite extensively. Current low step bikes on the market are split into fully mechanical or electrically assisted, with our bike falling into the prior category. On top of this, it was somewhat of an issue to find low step bikes designed specifically for men, as that particular frame shape tends to be for women. Electrically assisted bikes and some of the highest end mechanical ones could range from anywhere between £1500-£3000. These typically consisted of lightweight aluminium components with some featuring parts made from carbon fibre, weighing anywhere between 10 and 15 kilograms. For more standard mechanical bikes like our design, prices tend to range from £150 at the bottom end up to around £900 at the top, following a trend of an increase in price with a decrease in weight.

Conceptual Design

Morphological Analysis

At the start of our project we brainstormed initial ideas for each component of the bike and created a morphological analysis table. From this table we agreed on 3 different concepts for the bike we wanted to construct.

Features	Option #1	Option #2	Option #3	Option #4
Frame Shape	Diamond	**Step-Through**	Monocoque	Recumbent
Frame Material	Steel	**Aluminuim**	Titanium	Carbon Fibre
Frame Finish	Beed Blasting	Shot Peening	**Anodising**	
Seat Type	**Noseless**	Cruiser		
Seat Material	Rubber	**Nylon**	Leather	
Seat Padding	**Gel**	Foam padded		
Backrest Configuration	Basic pad	**Ergonomic**		
Backrest Material	Rubber	**Nylon**	Leather	
Handlebar Configuration	Straight	Bullhorn	**Sweptback**	Dropbars
Handlebar Grip Material	**Rubber**	Nylon	Leather	
Brake Type	Single Pivot Rim	**Dual Pivot Rim**	Disc	Pedal
Brake Actuation Mechanism	**Lever + Bowden cables**	Hybrid	Hydraulic	
Gear Configuration	**Single Gearset**	Dual Gearset	No Gearset	
Shifter System	**Interated Break Lever**	Indexed	Down Tube	
Selling Price	<100	**100>500**	500>1000	1000+

This was the first concept/design that we investigated from the table's results. The advantages of this concept include the step-through frame, which is suitable for our target user: 55+ males with back pain. This frame means that the man won't need to raise his leg over a top tube, therefore causing less strain. Using aluminium is advantageous as it is a lightweight material, making it easier to lift and manoeuvre. The downside is its weakness, meaning the tubes would need to be thicker than if they'd been of steel.

The frame finish we selected for this design was an anodising finish. This was to increase the corrosion resistance rate, reduce the impact of wear and tear and also for a stronger finish. The type of handlebars selected for this design was the sweptback configuration. The advantage of this configuration is that it promotes the correct posture for this type of bike, which is the upright posture, and this means that it will take strain off of the man's lower back.

The brake system selected in this concept was the dual pivot rim brakes which is typical in road bikes. These brakes provide a good stopping power and are easy to maintain which result in a long lifespan. We preferred a single gearset as the bike is designed for leisure and practicality rather than performance. The shifter system we decided on was an integrated brake lever system which is easy to operate. We wanted to keep the price reasonable for a long-lasting affordable bike.

The second concept for the bike kept some of the features of the original plan such as the frame shape and the shifter system. The main difference from the previous concept

Features	Option #1	Option #2	Option #3	Option #4
Frame Shape	Diamond	**Step-Through**	Monocoque	Recumbent
Frame Material	**Steel**	Aluminuim	Titanium	Carbon Fibre
Frame Finish	Beed blasting	**Shot peening**	Anodising	
Seat Type	Noseless	**Cruiser**		
Seat Material	Rubber	Nylon	**Leather**	
Seat Padding	Gel	**Foam Padding**		
Backrest Configuration	Basic pad	**Ergonomic**		
Backrest Material	Rubber	Nylon	**Leather**	
Handlebar Configuration	**Straight**	Bullhorn	Sweptback	Dropbars
Handlebar Material	**Rubber**	Nylon	Leather	
Brake Type	**Single Pivot Rim**	Dual Pivot Rim	Disc	Pedal
Brake Actuation Mechanism	**Lever + Bowden cables**	Hybrid	Hydraulic	
Gear Configuration	**Single Gearset**	Dual Gearset	No Gearset	
Shifter System	**Interated Break Lever**	Indexed	Down Tube	
Selling Price	**<100**	100>500	500>1000	1000+

was to use steel for the frame material. The advantage of using this material is that it is much stronger than aluminium meaning the tubes don't need to be thicker than normal. The downside of using this material is that it is a lot more dense than aluminium which means that is more difficult to manoeuvre. For this design we chose shot peening which prevents the propagation of cracks and prevents fatigue. We chose straight handlebars for this design but the downside of these handlebars are they promote an arched back causing strain to be put on the back. And the brake system that was chosen was a single pivot but compared to concept 1 the single pivot has less stopping power than the dual pivot. This design would be more affordable, but this would result in a decrease in the profit.

Features	Option #1	Option #2	Option #3	Option #4
Frame Shape	Diamond	**Step-Through**	Monocoque	Recumbent
Frame Material	Steel	**Aluminuim**	Titanium	Carbon Fibre
Frame Finish	Beed blasting	Shot peening	**Anodising**	
Seat Type	**Noseless**	Cruiser		
Seat Material	Rubber	Nylon	**Leather**	
Seat Padding	**Gel**	Foam Padding		
Backrest Configuration	**Basic Pad**	Ergonomic		
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Handlebar Configuration	Straight	Bullhorn	**Sweptback**	Dropbars
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Brake Actuation Mechanism	**Lever + Bowden cables**	Hybrid	Hydraulic	
Gear Configuration	Single Gearset	**Dual Gearset**	No Gearset	
Shifter System	**Interated Break Lever**	Indexed	Down Tube	
Selling Price	<100	100>500	**500>1000**	1000+

This was our third design which again kept some of the concepts from our previous designs, so they have the same advantages and disadvantages that have already been stated. The main change in this design is that the brake type chosen was the disc brake. This type of brake provides more stopping power and more precise braking and it is less likely to cause the wheel to lock up. A second difference is that we selected a dual gearset which allows greater speeds to be achieved.

So as a group we deliberated each design concept to see which one would be the best fit for our bike and our target consumer. The main design features we wanted were a lightweight bike that was easy to get on and off for older males and a bike that didn't strain the back in any way. For these reasons we chose concept 1 as this design is a lightweight but strong bike, it is easy to mount and demount with the step through frame shape and the handlebars promote the correct posture so there is no pain in the back. It also has a back rest and larger seat to provide extra comfort. The braking system is easy to operate and has precise stopping power. The bike is very affordable and long lasting so it is the most value for money.

QFD

This house of quality was used often in our project as a reference point. (Links in appendix)
Note: Δ = 1, o = 3, ⊙ = 9

Rider	Company			Mass of Bicycle	Back Support Angle	Wheel Size	Seat Height	Tyre Pressure	Cost of Material	Stiffness of Seat Springs	Angle of Handlebar Grips	Height of Back Support	Number of Gears	Lifetime	◇ Bicycle 1 ○ Bicycle 2 1 = very bad 5 = Very Good 1 2 3 4 5
				NOW											
			Direction of Improvement	↓	↓	↑	-	↑	↓	↓	↑	↑	↑	↑	
			Units	kg	°	inch	cm	psi	GBP per kg	N/m	°	mm	#	No. years	
25	18	WHAT – Performance	Support for Back	△	o	-	△	-	-	o	△	⊙	-	-	○ ◇
12	10		Control	△	-	⊙	-	△	-	-	-	-	△	-	○ ◇
17	12		Comfort	-	⊙	-	⊙	-	-	o	o	-	-	-	○ ◇
12	8		Ease of Cycle	-	-	△	-	-	-	-	-	-	o	-	○◇
5	10	Adjustability	Different Leg length	-	-	-	⊙	-	-	-	-	-	-	-	○◇
5	10		Torso Length	-	-	-	o	-	-	-	-	△	-	-	○ ◇
6	6	Other	Ease of Maintenance	o	-	-	-	-	△	-	-	-	-	-	○ ◇
10	8		Durability	o	-	-	-	△	-	-	-	-	-	-	○ ◇
8	10		Cost Effectiveness	-	-	-	-	-	⊙	-	-	-	-	-	◇ ○
0	8		Ease of Manufacture	△	-	-	-	-	o	△	-	-	-	-	○ ◇
			Bicycle 1	18.5	n/a	28.5	54	87	n/a	n/a	23	n/a	8	10	
			Bicycle 2	19.9	n/a	28	60	95	n/a	n/a	31	n/a	7	10	
			Target (delighted)	17.5		28		97			25	350	7	10	
			Target (disgusted)	25		24		70			35	250	4	5	

The above house of quality includes customer requirements, engineering specifications and competition benchmarking. As the table uses Δ = 1, o = 3, ⊙ = 9 as symbols of importance where the higher the number the more important that engineering specification is to the stated customer requirement.

The customer requirements were chosen through analysis of current bikes on the market and research into the target market of men of age +55 with back pain. As the main restrictive point of our brief is the back pain we decided to make the majority of our performance based requirements tailored to easing the stress on the back.

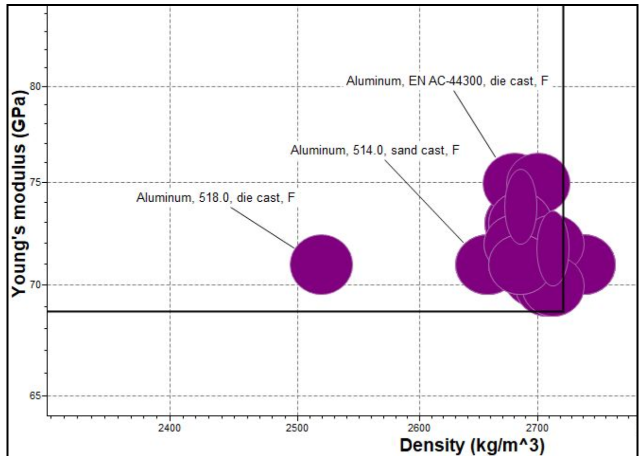
Regarding the engineering specifications we chose a broad range, including general bike specifics to parts and measurements that would only be found on our bike. The specifications unique to our bike were hard to find existing product values so we have left a few gaps in the table. We used two existing dutch style upright style bikes designed for men as a comparison.

Detailed Design

In this section we will discuss the designs of components of our bike and why we chose each aspect and dimension alongside with detailed CAD renderings displaying these.

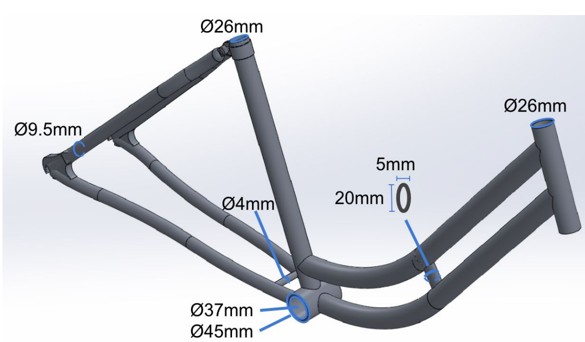
Frame

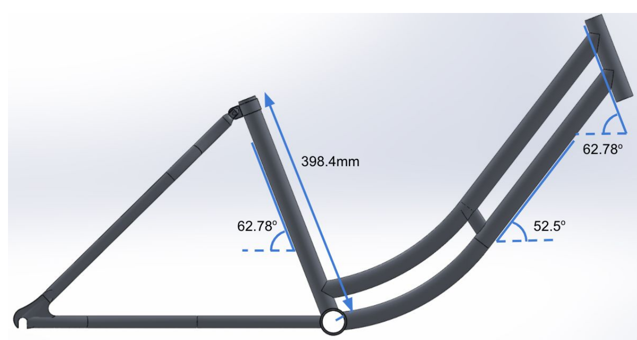
As stated previously, aluminium was chosen over steel and titanium for its low density, however the exact alloy of aluminium had to be chosen. Using CES software, aluminium alloys were projected onto a graph of Young's Modulus vs density in order to find the stiffest alloy for the lowest density. These were then ranked by cost per kg, and from this deduced that Al-518 would be the best option to pursue. This is shown on the right-hand side.



Name	Price per unit volume
Aluminum, commercial purity, S15...	4.02e3 - 4.83e3
Aluminum, 518.0, die cast, F	4.18e3 - 4.93e3
Aluminum, 514.0, sand cast, F	4.4e3 - 5.19e3
Aluminum, 443.0, sand cast, F	4.46e3 - 5.27e3
Aluminum, A413.0, die cast, F	4.47e3 - 5.22e3
Aluminum, 413.0, die cast, F	4.47e3 - 5.24e3
Aluminum, A356.0, sand cast, F	4.47e3 - 5.27e3
Aluminum, A356.0, permanent mo...	4.47e3 - 5.27e3
Aluminum, A356.0, permanent mo...	4.47e3 - 5.27e3
Aluminum, A356.0, sand cast, T6	4.47e3 - 5.27e3
Aluminum, 356.0, investment cast...	4.48e3 - 5.27e3
Aluminum, 356.0, sand cast, F	4.48e3 - 5.27e3
Aluminum, 356.0, sand cast, T6	4.48e3 - 5.27e3
Aluminum, 356.0, permanent mold...	4.48e3 - 5.27e3
Aluminum, A360.0, die cast, F	4.5e3 - 5.27e3
Aluminum, 360.0, die cast, F	4.5e3 - 5.27e3

Dutch bikes have a step-through frame, allowing for easy use for women with skirts or dresses. Though our bike is destined for use by males, the lack of a horizontal tube reaching from the fork to the seatpost would reduce the height required by one to swing a leg over, and therefore is appropriate for a user with a more restricted range of motion. , meaning the diameter of the tubes had to be increased to compensate for the lower stiffness. Straight gauge tubing was preferred for its ease of manufacture, and vertical wheel dropouts for ease of wheel-changing. Finally an anodising finish would increase corrosion resistance, reduce the impact of wear and tear with a harder finish.

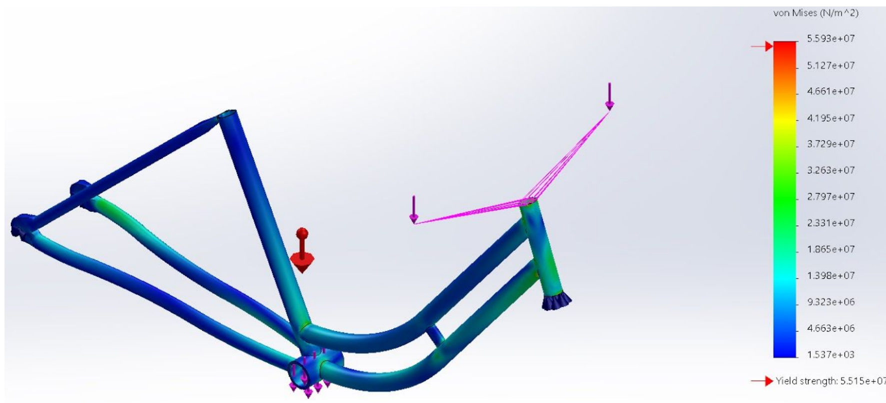




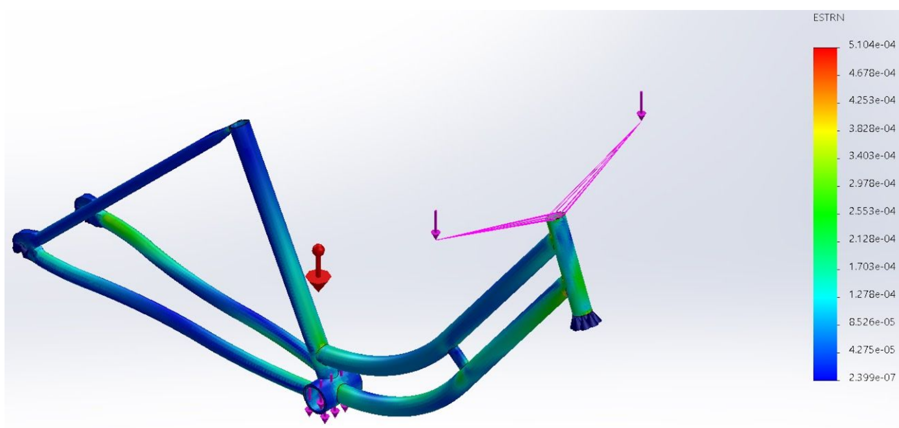
Finite Element Analysis (FEA)

A static FEA simulation was run on the frame to make apparent structural weaknesses. For this a 130kg downward load was applied in the main axle, with another 10kg on the grips on either side of the handlebars. The bearing supports are on the rear dropouts and on the lower face of the front of the frame where the fork would be pushing up against. Using a fine (5x2.5mm) standard mesh size, the simulation produced the following stress and strain charts, along with static displacement and Factor of Safety charts which can be viewed in the appendix. Overall the structure clearly retains its integrity in the hypothetical scenario provided, though apparent stress concentrations resulted in a thickening of the inside of the horizontal tubes closest to the rear dropouts, as well as larger fillets where the two curved diagonal tubes join the fork holder and main tube near the axle.

Stress Chart.

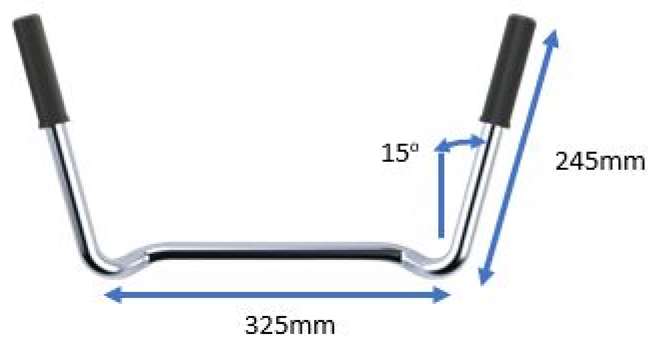


Strain chart.



Handlebars

After going through the different configurations, we decided that the best handlebars to use would be the sweptback handlebars. These handlebars are traditional to the Dutch style bike and are swept back towards the rider as this allows for a comfortable positioning of the wrist and hands; it also promotes better back posture unlike other handlebar configurations such as drop down or flat handlebars. This agrees with our specification as the promotion of good back posture will help to prevent back strain. The material used to make the handlebars which is aluminium 518 die cast, the same type the frame will be made from. This is to ensure that the bike is lightweight and easy to manoeuvre. The material choice for the grips for the handlebars would be rubber; this is to provide the right amount of comfort for the rider's hands and to ensure that his hands do not slip during a ride. This material has a high degree of water resistance so it is able to survive longer in harsher weather whereas another material choice was leather but this was ruled out due to not being as waterproof and not providing a better grip than rubber however it may have provided more comfort. The angle that the bars are swept back towards the rider is 15 degrees; this was used to make sure that the maximum comfort and correct sitting posture would be achieved. The dimensions are based on averages for a standard male age of 55+.



Chain and gears

Chain calculation

A simple steel roller chain was chosen due to its compact size and ability to support high tensions with easy maintenance. For the chain calculation we elected a selection power of 150 watts for a male aged 55+ for between 30 minutes to an hour of peak power. We wanted to choose the highest gear ratio for a typical road bike. The values for the gear ratio were gathered from this table and the gear ratio/reduction ratio was found to be 53/13 which was 4.08

Chain ring	39	53				
Block	13	14	15	16	17	19	21

The next step was to find out the application factor from the table provided. From this table the application factor was chosen to be 1.0 as this is the typical application factor for a road bike.

Driven machine characteristics	Driver characteristics: Smooth running, eg electric motors, IC engines with hydraulic coupling	Slight shocks, eg IC engines with more than six cylinders, electric motors with frequent starts	Heavy shocks, eg IC motors with less than six cylinders
Smooth running, eg fans, pumps, compressors, printing machines, uniformly loaded conveyors	1	1.1	1.3
Moderate shocks, eg concrete mixing machines, non-uniformly loaded conveyors, mixers	1.4	1.5	1.7
Heavy shocks, eg planars, presses, drilling rigs	1.8	1.9	2.1
Reproduced from Renold, 1996			

The next step was to find the tooth factor. This was calculated by dividing 19 by the number of teeth on the small sprocket, 13. Our tooth factor was 1.46. This means that the selection power, which is calculated by multiplying the peak power by the application factor and the tooth factor, was found to be 219 watts. Once that was calculated the driver sprocket speed was calculated by multiplying the cadence by the reduction ratio, 308 revs per minute. The next step was to find out the pitch of the chain which is the length between each tooth. This is found by comparing the results to the table provided. It can be seen from the table below that the pitch for our bike would be an 8mm. From this the centre to centre distance of the sprockets can be found by using the equation below.

$$C = \frac{p}{8}\left[2L - N_2 - N_1 + \sqrt{(2L - N_2 - N_1)^2 - \frac{\pi}{3.88}(N_2 - N_1)^2}\right]$$

And this was found to be 413mm and using all of these results the number of pitches that are required for the chain can be calculated using another equation which is shown.

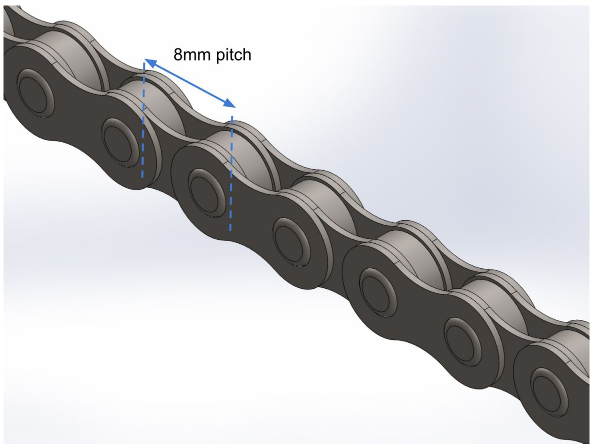
$$L = \frac{N_1 + N_2}{2} + \frac{2C}{p} + \left(\frac{N_2 - N_1}{2\pi}\right)^2 \cdot \frac{p}{C}$$

Using this equation the number of pitches required was found to be 137. The last property of the chain that has to be calculated is the lubrication method that needs to be used.

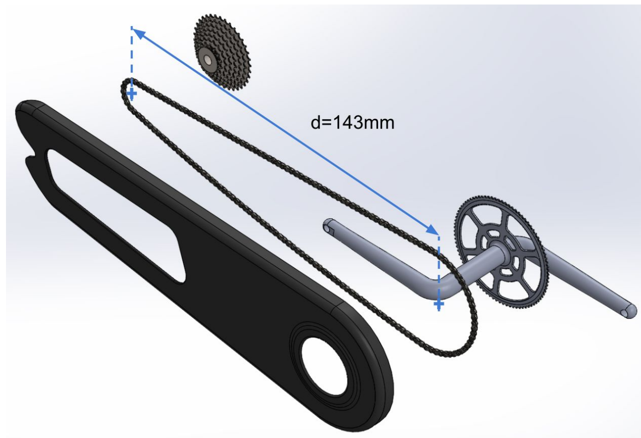
Again this can be found using the table that was used to find the pitch and from the table the lubrication method that should be used for this chain is manual lubrication.

So as can be seen below, the chain pitch is 8mm with 413mm between the crankset and the sprockets, with 137 pitches . An ABS polymer chain-guard is added overtop to protect the externally-lubricated chain from the elements, thereby reducing the need for maintenance. Containing moving parts also has the advantage of reducing the risk of injury.

Close-up of chain links.



Exploded view of drivetrain mechanism.



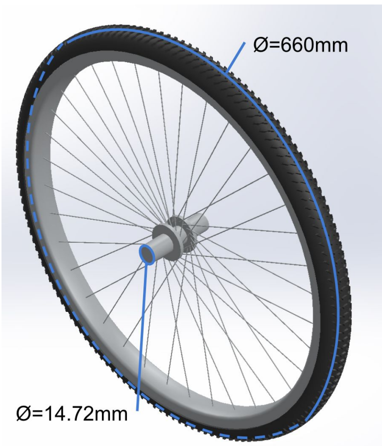
Brakes and Shifter

The most common mechanical actuation method for brakes in a modern bike is a combination of brake levers coupled with bowden cables which are attached to brake arms that when moved, force pads against the braking surface. This combination of brake lever, bowden cables and pivot rim brakes is the configuration we chose to implement into our design.
This brakes work by compressing the brake lever which pulls on the bowden cable putting it in tension, that force is then transferred onto the rim brakes which due to the tension force and forced shut, clamping onto the rim of the tyre slowing it down.

As our bike is not designed to reach high speeds extreme brakes are not required which is why short lever pull brakes, standard for road bikes, are our brakes of choice. These not only allow for the shifter for the gears to be integrated into the brake lever but give more than sufficient braking power. Within the brake lever we would implement a trigger shifter which utilises the thumb and index finger positioning to allow for easy gear change.

As with the brake lever we are using a standard single pivot rim brake for the actual braking mechanism. The use of standardised components would mean that we would not be required to manufacture our own saving money on both design and manufacturing costs. Simple brake lever models were created to give some idea of what they'll look like on the bike.

Wheels and tyres



For the wheel, spokes were chosen for their high tensile strength and ability to adjust rim alignment in the event of it buckling due to a strong lateral impact. The tyre is composed of a rubber-nylon compound that is not only durable and cheap, but also perfect for high friction on paved and wet surfaces, enabling all-weather use in an urban setting. A tread also provides increased friction to prevent the ride from slipping. The front wheel axle is smaller and is only 10mm in diameter as it doesn't have to house the sprocket.

The Seat

Research - Noseless Bike saddle

The noseless bike saddle alleviates pressure from the groin and cradles the "sitting bones" for optimal comfort. This allows for a much more comfortable ride and ensures proper blood supply which reduces feelings of numbness. Studies show that 60% of people using nosed saddles reported genital pain and numbness [3]. For this reason removing the nose of the saddle makes for a more comfortable ride.

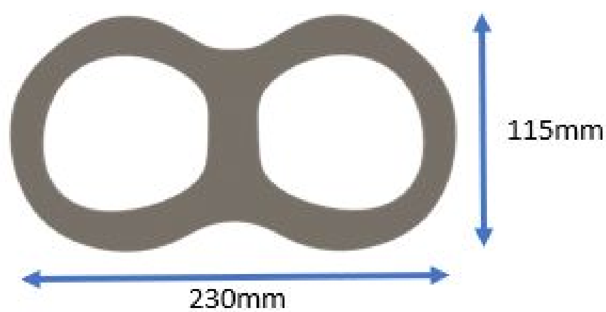
This seat was chosen as it provides the most comfort. The numbness from use of a conventional bike cruiser saddle and chaffing from a cruiser bike saddle provides additional discomfort so the cruiser saddle wasn't chosen.

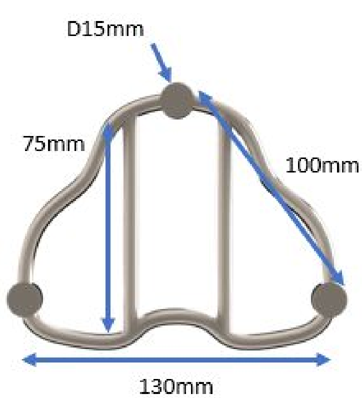
Dimensions were researched and the distance between the ischium (or "sit bones") was found to be an average of 120mm apart in males however when sitting on firm surfaces like a bike seat, this distance should be 135mm [4].

Design - Saddle

The saddle is shaped to the glutes and is designed to support the user whilst not providing any discomfort. The saddle will be a gel covering as it provides the maximum comfort. The saddle design cradles the ischium with its convex shape which is important for a very comfortable ride. The dimensions of the saddle show the troughs of the seat are 135mm apart which is the optimum distance apart as researched, this shape and design will help promote proper circulation in the lower half of the body.

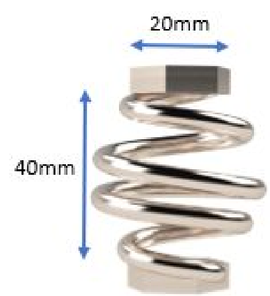
Underneath the saddle is a metal plate with a similar shape to the saddle which will provide some mechanical support for the seat. This also provides a surface between the suspension and the seat and allows the suspension to be spread more evenly. It was originally designed to have the springs screwed in, however having the suspension permanently joined was a better option so the springs cannot come loose. The metal plate has portions cut out to allow some flexibility in the seat where the user can sink in so the seat can conform more to the user's shape.





The lower part of the seat consists of a support structure which is shown in the image on the left. The shape of the structure has no discontinuities as these become focal points of stress. The circular connectors will be welded to the ends of the suspension springs for a good connection. The springs are spread out as so to provide stability to the user and spread the weight out more.

The rods on the inside of this structure are where the seat post will clamp onto. These are 75mm long allowing for adjustment on the user's part as to the distances to the backrest and the handlebars.



An image of the spring is displayed on the right, it consists of a coiled spring which tapers to two hexagonal connectors, these shall be welded to the appropriate points as shown in the images of the bike seat.

The materials used for the springs will be stainless steel type 302, this is because this type can be drawn into a wire form as required, it also has a medium level strength compared to the others with a young's modulus of ~180 GPa which will be strong enough, especially since there are 3 springs with the weight distributed between them. A table of different stainless steels used in springs is below, comparing their different properties.

STAINLESS STEEL	FORM	STRENGTH	COST	HEAT TREAT	CORROSION RESISTANCE	OTHER
TYPE 302	WIRE	MEDIUM	MEDIUM	NO*	MEDIUM	BEST VALUE
TYPE 17-7	BOTH	HIGH	HIGH	YES	MEDIUM	HIGH PERFORMANCE
TYPE 316	BOTH	LOW	HIGH	NO*	HIGH	CRES
TYPE 304	BOTH	VARIOUS	MEDIUM	NO*	MEDIUM	GENERAL PURPOSE
TYPE 301	STRIP	MEDIUM	MEDIUM	NO*	MEDIUM	BEST VALUE
TYPE 430,440	BOTH	LOW	LOW	YES	LOW	GENERAL PURPOSE

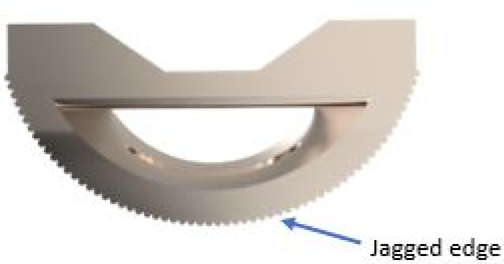
Table [6]

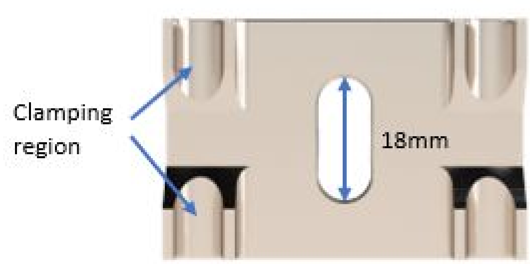
The corrosion resistance is also reasonable compared to the other stainless steels. Stainless steels generally have a good corrosion resistance due to a chromium element of 10%-20% meaning their corrosion resistance is good which makes them perfect for the bike material [7]. As seen the cost is average but since there are only 3 springs costs can be kept low for a very important part.

The material used for the other parts of the seat will be aluminium 518 as it is light yet strong and also cheap, keeping costs down whilst not yielding mechanical integrity.

Design - Seat post

The seat post design allows for the angle of the saddle to be adjusted as the angle of the seat is important in encouraging the user to maintain straight posture whilst cycling [5]. This is done with complimenting jagged edges on the edges of the clamp and the seat post. When the bolt is tightened high frictional forces will fix the saddle at an angle and the top and bottom clamps will tighten around the lower part of the seat. The curved bottom of the fastener allows it to be tightened at a range of angles. The holes in the top and bottom clamps are elongated to also accommodate a range of different angles, this can be seen in





the examples below as well as a closer view of the jagged edge. Further diagrams are displayed in the appendix in figure 1.

The seat post top and bottom clamping parts will be manufactured from stainless steel grade 304, this is a common stainless steel with high chromium percentages which gives it good corrosion resistance. The seat post itself will also be stainless steel as it will take most of the weight of the user, this goes with the specification requirements that the bike will be able to support a 130kg male and still remain functional. The hex bolt, washer and fastener will also be fashioned from the same stainless steel.

The Backrest

Research - Spinal Dimensions

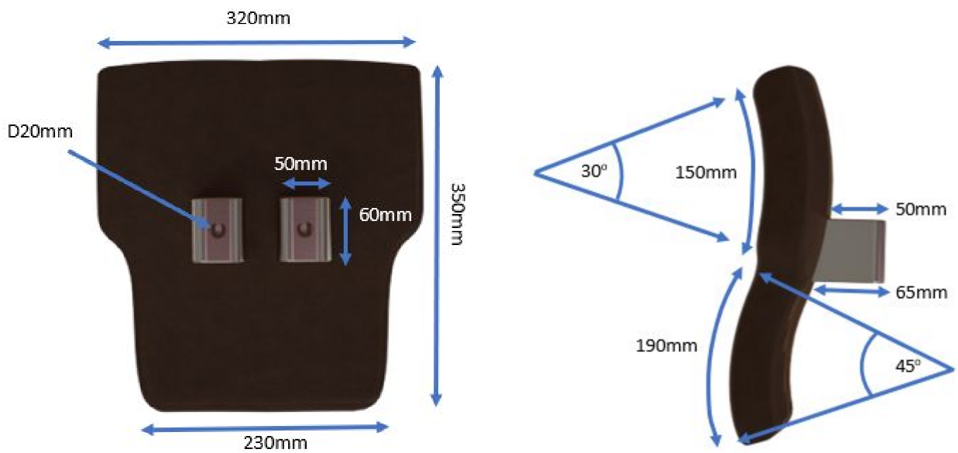
The average angles in the spine are displayed in the image (can be found in the images section) for the lumbar support; a normal angle for the lumbar lordosis is 45 degrees. Lumbar lordosis is the name for the curvature of the in the lower, lumbar region of the spine. In the lower, or lumbar, region. The normal angle for Lumbar Lordosis is actually very varied and can be in the range of 30-60 degrees. The Lumbar region of the back ranges from vertebrae L1 to 5, this part of the back bears the most weight and is the part of the back where the most problems occur [8].

The thoracic region of the back is the largest region and is made up of 12 vertebrae. These connect to the ribs and sternum. This part of the spine is very stable and causes fewer back problems. The average length of this part of the back was calculated to be roughly 190mm by adding together the vertebrae dimensions and the distances between them [9].

Design - The Backrest

A backrest allows the rider to relax their lower back muscles and provide support and good posture so as not to worsen the rider’s pre-existing back pain.

The backrest design featured a concave design to fit the shape of the users back to provide as much comfort as possible. The backrest will consist of an aluminium frame which has a thick padded layer over it to make it comfortable on the back. The images below show the measurements of the backrest, these were taken from average adult male measurements to be comfortable for the average male back. The mean length of the lumbar region was calculated to be roughly 190mm long. This will constitute the length of the lumbar region of the back support. The lumbar region was found to have an angle from 30 to 60 degrees which is a large range. Therefore, the back rest was formed to a 45-degree lumbar lordosis to accommodate the median.



The backrest will be attached to a frame which has multiple holes in it of diameter 20mm which are in line with the backrest holders, these holes allow for the height of the seat to be adjusted to accommodate varying heights of bike users. The screws that fix the backrest in place were deliberately thick as they will bear the load so a diameter of 20mm was chosen. This secondary frame only has an outer and inner diameter of 23mm and 20mm respectively, this is a lot narrower than the main frame of the bike as it needs to bear less load as most of the weight will be on the seat post and the frame, this also cuts down excess weight. This will also be made out of aluminium 518 as it is lightweight and relatively strong.

The backrest is attached to the frame through another part which is attached to the frame, this part has two slots in it in which the secondary frame can just slot in, this is a convenient way to attach the backrest as if the user does not wish to use it, it can be easily detached. As not a lot of load will be placed on the backrest, a more sturdy option for attachment isn't very necessary. The image displaying the design can be found in the appendix in figure 2.

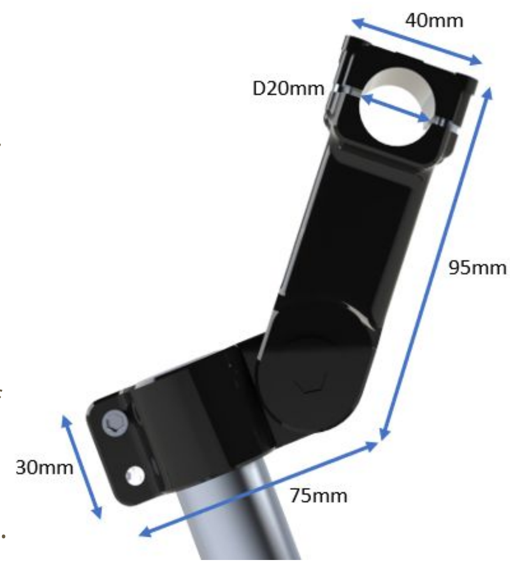
The Fork

Design - The Fork

The fork of the bike was designed as a classic dutch bike fork with a slight curvature, this design gives enough support as most of the weight will be towards the back end of the bike. We chose this shape to keep to the dutch style of the project brief. No suspension was added as this would add considerable weight, so large springs were added under the seat to compensate. A rendered cad model with measurements as well as a close up view of the slot in which the wheel axle fits into can be seen in the appendix in figure 3.

Design - The Stem

The stem of the bike is what connects the handlebars to the fork. This was designed to allow for the adjustment of the height and angle of the handlebars. The stem attaches to the fork and handlebars through clamps which can be tightened easily by bolts. The adjustability of this design allows the bike to accommodate a range of differently sized riders allowing them to adjust the angle and height of the handlebars as well as how close or far away they are. This part will also be made out of aluminium, as it's not a load bearing part and will keep the bike light.



Standards considered

The european standards for city and trekking bikes, EN14764, is what we used for the design requirements of our bike [10]. We went through the basic requirements for the dimensions of each of the parts we designed and made sure it adhered to the standard required by legislation. Any extra pieces that were listed in the standards were also added to the bike design.

Handlebars

- Width between handlebars is 475mm which is within the range of 350mm to 1000mm (4.7.1).
- Vertical distance between the highest handlebar position and the lowest seat position is 160mm which is less than 400mm (4.7.1).
- Handlebars have been fitted with hand grips (4.7.2).

Front fork

- Slots in the front fork are designed so that when the wheel axle is abutting the top face of the slot the wheel will be kept centrally aligned by having the fork slots symmetrical in height and shape. The distance between the slots allows them to fit very closely to the flanges on the front wheel and when tightened with the nuts the fork will hold the wheel in a central alignment (4.9.2).
- An attachment point for caliper brakes has been added to the fork and to the back of the frame since brakes are intended to be fitted (4.9.7.1).

Wheel tyre assembly

- The alignment of the wheel tyre assembly has a clearance of 8mm from the fork on the sides and a clearance of 8.5mm from the mudguard (4.10.2).

Pedals

- Since the pedals are toe-clip pedals, they have tread surfaces on the top and bottom surfaces of the pedal (4.13.1.2).
- The pedals definite prefered position is with the treads on the top and bottom faces, which automatically presents the treads to the rider's foot (4.13.1.2)
- With the pedals unladen, and the pedal at the lowest point with the tread surface parallel with the ground. The bike is capable of being leaned over at 25 degrees from vertical without the pedals touching the ground, it can reach an angle of over 45 degrees (4.13.2.1).
- The clearance between the pedals and the front mudguard is greater than 100mm for foot clearance longitudinally from the arc of the mudguard. The smallest clearance is 150mm (4.13.2.2).

Saddle and seat post

- No part of the saddle is 125mm above the top saddle surface at the point where the saddle surface is intersected by the seat post axis (4.14.2).
- The pillar has a permanent transverse mark the length of the external diameter of the seat post. This indicates the minimum insertion depth of the post into the frame. This mark is 70mm above the bottom of the seat post which is greater than 2 times the diameter of the seat post which is 26mm (4.14.3).

Bike chain

- The bike chain is fitted with a chain guard as required, this guard shields the side plates and top surface of the chain, as well as the chain wheel, the minimum distance is 25mm rearward along the chain from where the chain teeth first pass between the side plates of the chain. However our chain guard design completely covers it (4.16.3).

Lighting and reflectors

- The lighting and reflectors are not necessarily needed but national regulations must be adhered to for UK legislation (4.20.1).

Other Requirements

Pedal Bicycle Safety Regulations (PBSR) are in place to make sure that new bicycles are safe to be sold. The specific requirements for these are as follows:

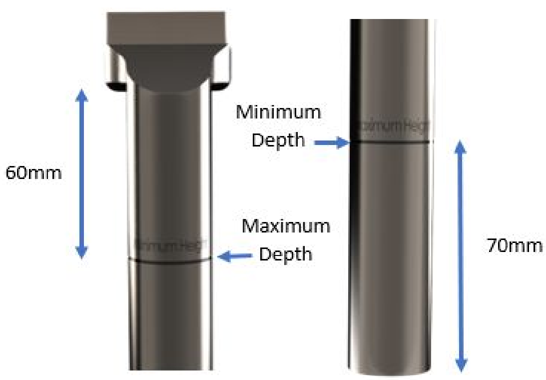
- Hand operated brakes that are arranged with the left brake lever for the rear brake and the right brake lever for the front brake.
- A bell
- A white front lamp or wide-angled reflector
- A red wide-angled reflector

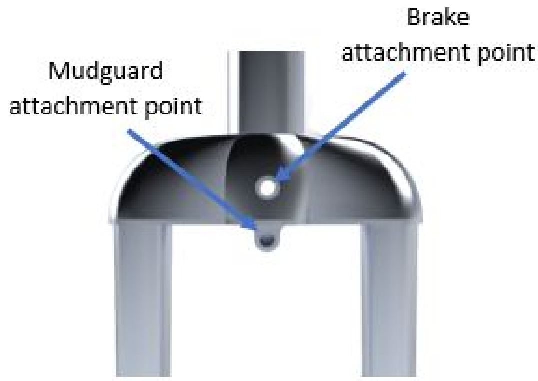
- Yellow reflectors on the front and rear of each pedal

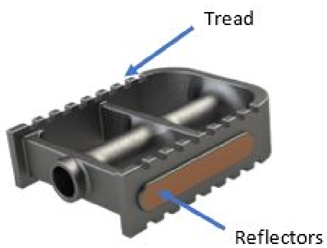
Yellow reflectors were added to the pedals as required and the brakes will be arranged as so. A bell was also added as well as mounting placements for a lamp on the front and a wide angled reflector on the back. A bell can easily be attached to the handlebars and there is plenty of space for a bell to be added to the bike. The image below shows the safety features added to the bike.

As seen in the model, there are no brakes fitted, however when brakes are attached they should be wired accordingly with the left brake lever corresponding to the rear brake and the right brake lever controlling the front brake. The rear mudguard was fitted with a skirt guard which stops items of clothing getting caught in spokes, however there is a space left in it for a wheel lock and brakes. The skirt guard was also added to give the bike a traditional dutch bike look.

In the image on the left, the added relevant markers that were added are displayed and on the right shows the brake attachment point added on the fork.







The pedal image on the left shows the tread on the top and bottom surfaces which is automatically displayed when the user uses the pedals. In addition, it also has front and rear reflectors which adhere to the lighting and reflector legislation.

Images

The following section contains rendered images of the bike from Solidworks Visualise. The first is a base functional model of the bike, showing the chain and the sprocket, as well as the pedal crank while the second image shows the bike with all of the extra parts added on such as the mudguards and reflectors as well as some images of the front and back.




In conclusion with our detailed design we managed to keep the traditional bike style as much as possible with the step-over frame and managed to our own additions accordingly whilst allowing the bike to fulfill it's functional requirements, mainly being as comfortable as possible and supporting a good posture.

Costing

Work cost

We estimated that the work labourers would be paid £10 per hour and would be working for 0.5 hours with an overhead rate of 280%. The work material that would be used would cost £9 with an overhead rate of 160%. This means that the total labour cost would amount to £28.40 this could be reduced by introducing automation which would decrease the amount of time the workers had to work.

Design cost

We estimated that the designers would be paid £65 per hour and they would be working for 150 hours with an overhead rate of 250%. The design material cost would be £5000 with an overhead rate 150%. This would result in the total design costs being £31875.

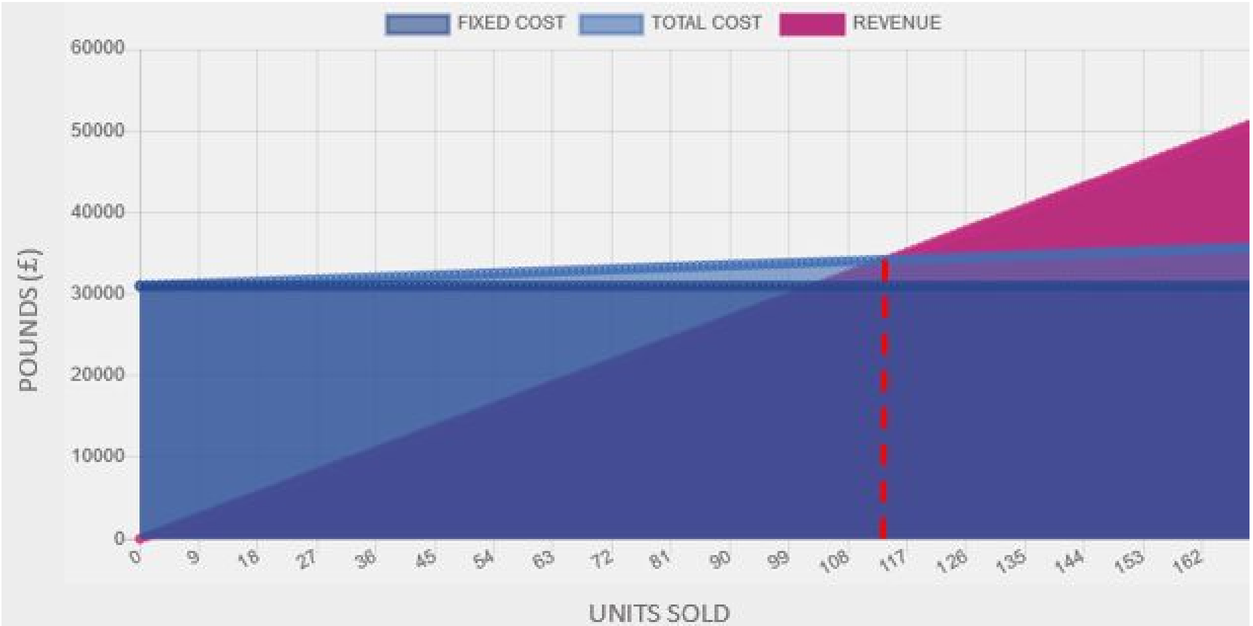
Selling Price

Using the equation below, with a commercial overhead rate of 125%, the selling price can be worked out when producing 100 bikes and 10000 bikes. Without profit when producing 100 bikes the selling price would be £433.94 to still agree with our morphological the maximum profit that we could have would be £66.06. when producing 10000 bikes the selling price would be £39.48. Again, to agree with our morphological analysis the minimum profit that we could have is £60.52.

$$profit\ +\ [(works\ cost\ price)\ +\ (\frac{cost\ of\ design}{quantity})]\ \times \%commercial\ overheads$$

Break even Chart

Below is the break even chart created from the analysis of the costs of the labour and fixed design costs. For this we used a selling price of £300 pounds, and set the variable unit costs at £28.40 this gives us a profit per unit of £271.60. With these costs and prices 114 units must be sold to break even.



The cost of production in reality is likely to be much higher as many of the parts will have to be bought in from other companies such as the handbrakes, mudguards and seats for example. Certain parts may have higher labour costs and such so realistically the cost per unit will probably be around £50-£70 however, without getting quotes from manufacturers this is very hard to estimate.

Return on investment (ROI)

The ROI can be calculated by taking total return on investments and dividing it by the total costs. The equation is shown below.

$$ROI = \frac{\text{Net Return on Investment}}{\text{Cost of Investment}} \times 100\%$$

As an estimate, the number of units sold a year will be 300 units. Using the equation above the ROI was calculated after three years of the first sale. Taking into account the design costs of £31,875 and the manufacturing costs of £28.40 for each of the 300 units produced for this demand annually. The net return on investment per unit is £271.60. With these numbers the ROI calculated is 425.6% which is very high. This would mean the investment return would quadruple what was put in originally.

However, if more realistic manufacturing costs are used of £70 with a profit of £230 then the ROI will be 220.2%, this is more realistic however this ROI doesn’t take into account many overheads a bicycle company would have such as rent and general staff salaries so in reality it would still be much lower.

Project Evaluation

Looking back through the project we all feel we have achieved what we set out to. We have ended up with a bike design and fits and matches our original requirements. The bike was supposed to be as comfortable as possible and support the user in an upright riding position to promote good back posture.

This was done by creating as comfortable a bike saddle as possible and creating a backrest which properly supports an upright riding position and conforms to the shape of the back. The bike is also relatively light, which was achieved through the use of lightweight aluminium, allowing for high maneuverability when off the bike, allowing the user to exert less physical strain when moving or picking up the bike. Solidworks calculated the bike to weigh roughly 10kg, in comparison most dutch bikes are 20kg so we succeeded in making a lightweight variant of the bike.

Longevity was also taken into account and the materials used are all resistant to corrosion which will allow the bike to last for a long period of time, hopefully up to 15 years however, this may vary with the weather conditions as well as the environment and how well the bike is taken care of.

Safety and standards were also taken into account and the european standards were considered and implemented on the bike design, however physical testing could not be carried out.

The brief specified a dutch bike style and the design we produced managed to stick to the traditional design with the shape of the handlebars, frame and mudguards as well as other parts. All in all we managed to fulfill the functional requirements of the bike using dimensions for the desired 55+ age group of males, and keep the stylish design of a traditional dutch bike.

Analysis of group

At the start of this project only two of our group members knew each other and we had not worked together on any previous tasks. To ensure a good working environment and a high standard of work throughout we needed to get to know each other's strengths and work methods as to function as a group.

Meetings

Due to all of us doing different subjects organising times was often a tricky task as we were in different lecture groups. With this in mind it was hard to fit meetings in during the days as our break hours rarely matched up. This left the time at the end of the days as our prime meeting time.

At the start of the project we were meeting once a week and taking rough notes on each meeting. During these meetings we would discuss what each of us had accomplished over the past week and then set out new goals that we would want to achieve by the time of our next gathering. Each group member would be assigned an aim or two to ensure that no task was neglected.

After the interim presentations we upped our meeting frequency to twice a week as to more accurately achieve smooth crossover between similar tasks that were being completed by multiple persons. One meeting at the start of the week and one at the end gave us two periods of work (weekdays and weekend) in which we could complete the tasks assigned to us. This change increased our work efficiency but also required better meeting minutes to be collected, stored and shared throughout the group.

These frequent meetings were in use up until the lockdown of the university due to the covid-19 outbreak. Since then we have had to rely on messaging within our group chat to communicate. By this time we had become more used to working with each other and did not require to be present to complete work so the isolation didn't hinder us too much.

File Exchange

At the start of the project we decided to make a google drive in which to store all of our individual and communal work. This worked very well as it allowed for multiple people to access and work on one document simultaneously while also including facilities such as powerpoint, excel and word in which to work on. We carried on this google drive right up to the completion of the final report on it.

In terms of file exchange, cad files complicate matters a bit as they cannot be included within the google drive. This problem was fixed with the solution of creating a mailing list in which all official documents were sent rond to each individual so that we all had copies.

Planning

The planning and time management of this project evolved as the design itself did. This was due to previously unknown factors and unforeseen events taking place. This meant that we had to be slightly flexible with timings but still had to try our best to stick to the dates first set out. With this in mind we altered our gantt chart only twice and managed to stick to it with only slight leniency in light of the lockdown situation.

Regarding the planning of the project itself we tried to play to each individuals strengths as much as possible and were able to more or less equally split the workload amongst the group. Each individual took the lead in their assigned area, this allowed for all of the group to take a leading role at one point or another throughout the project. Using the gantt chart as reference you can see which areas each member took either a lead in.

With each individual leading their own areas of the project it was important that we kept in mind the end project throughout to ensure everybodies areas came together in a coherent and efficient manner from no overlapping in research to the cad model fitting together meticulous planning and good communication was key.

Examples of each area of leadership was as follows:

- Finlay - CES and ROI
    - CAD: seat, backrest, fork, skirt guard, mudguards, reflectors and front light
- Craig - Chain calculations and costing
    - CAD: handlebars
- Adrien - Part materials and FEA
    - CAD: frame, crankset and pedals, gears, chain and chain guard
- Callum - Market and target research
- Ewan - QFD and general overseeing

These are only a few of the areas in which each member took leading roles that all came together to produce the overall project and final bike design.

Appendix

Figure 1 - Seatpost attachment

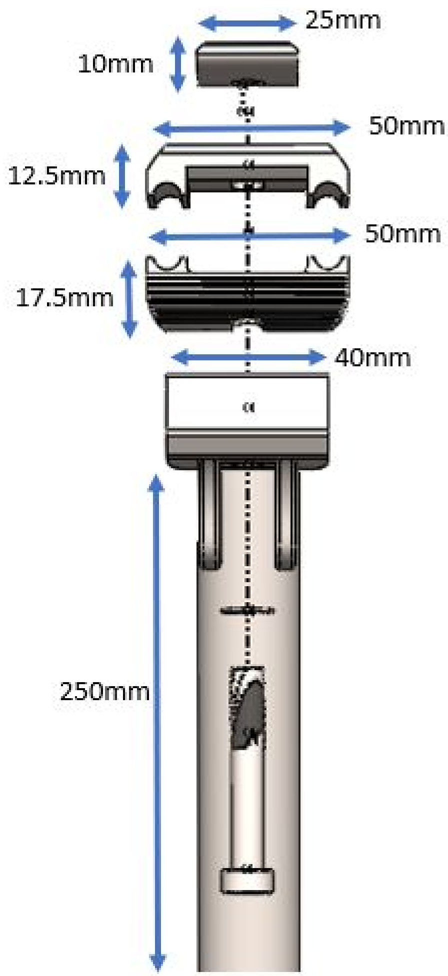


Figure 1.1

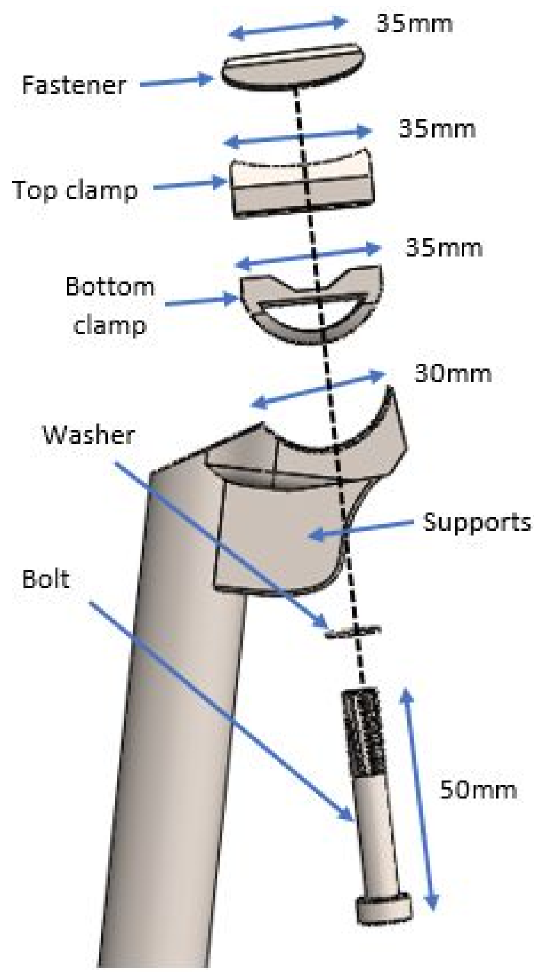


Figure 1.2

Figure 2 - Back rest support

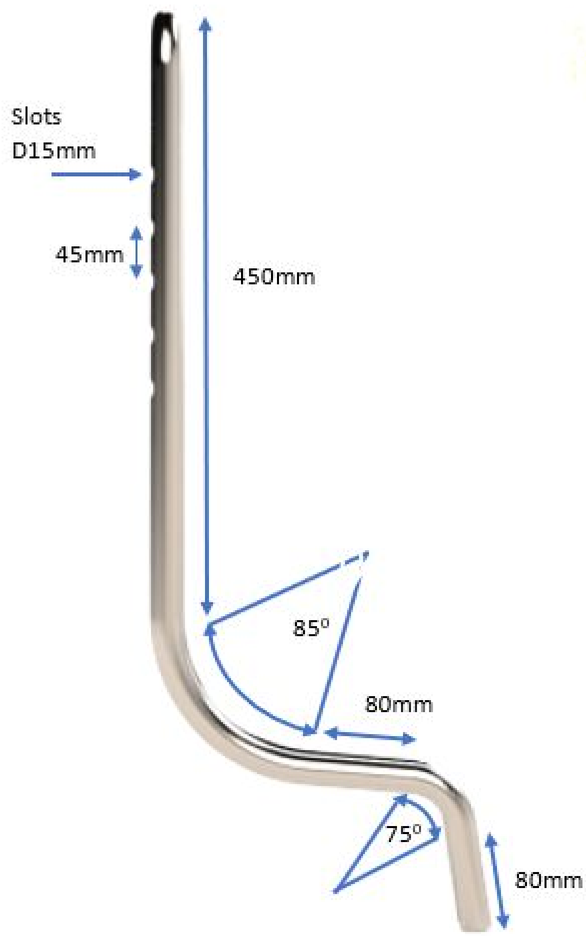


Figure 3 - Fork

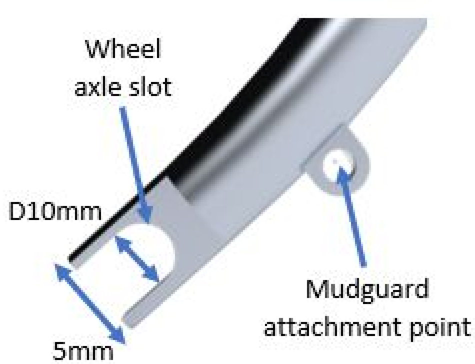


Figure 3.1

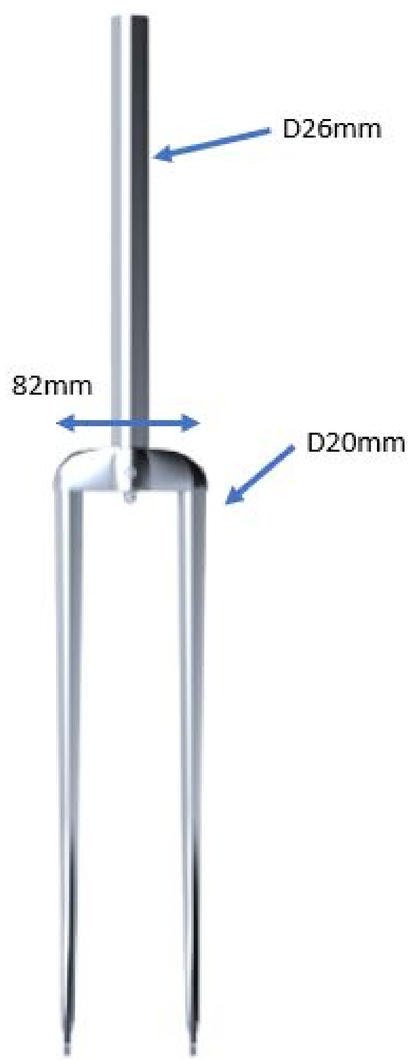


Figure 3.2

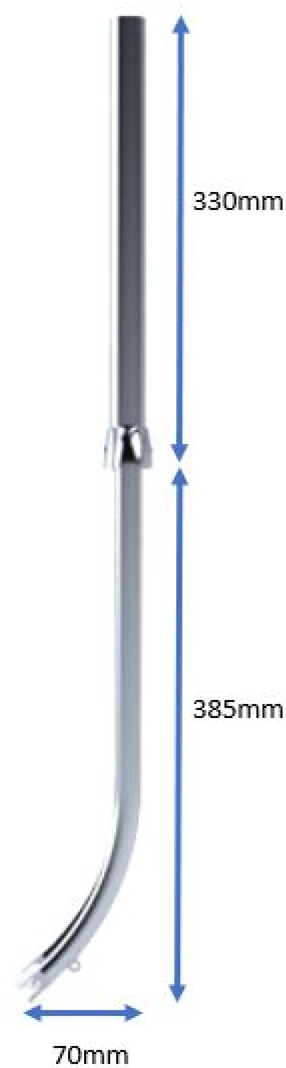


Figure 3.3

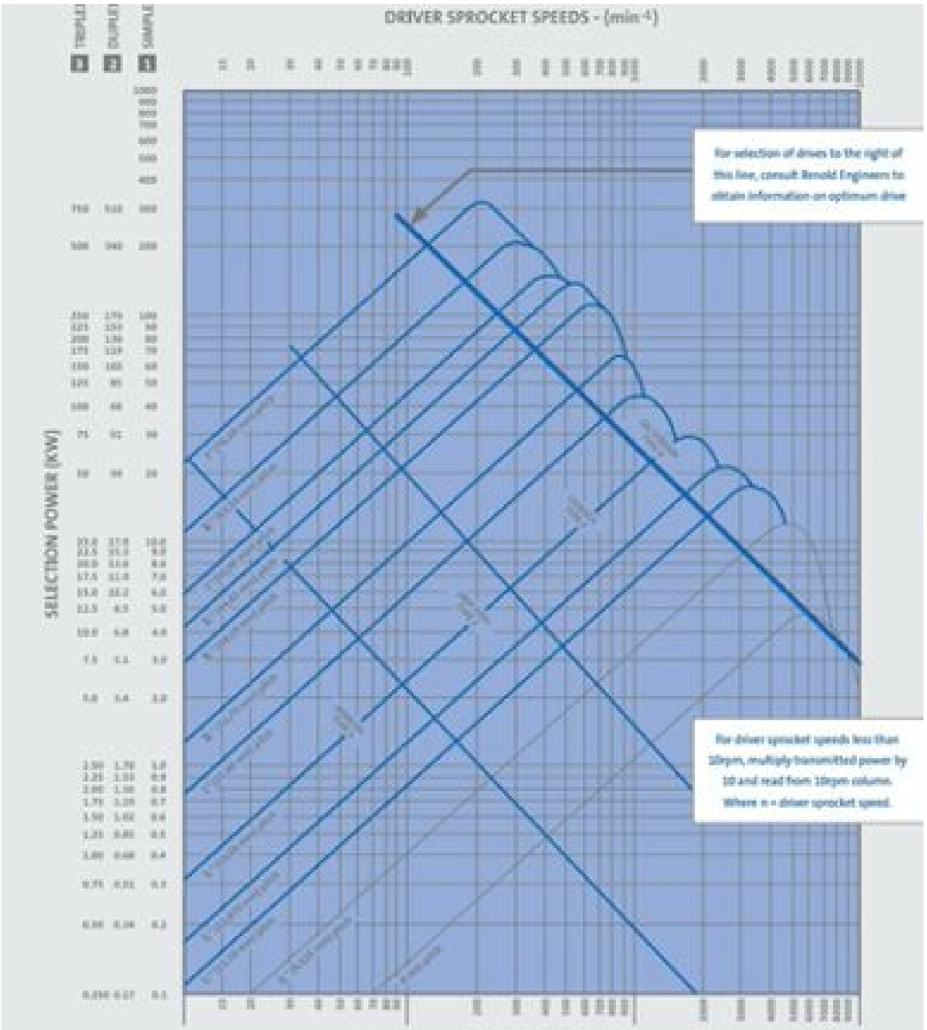


Figure 4 - chain pitch table

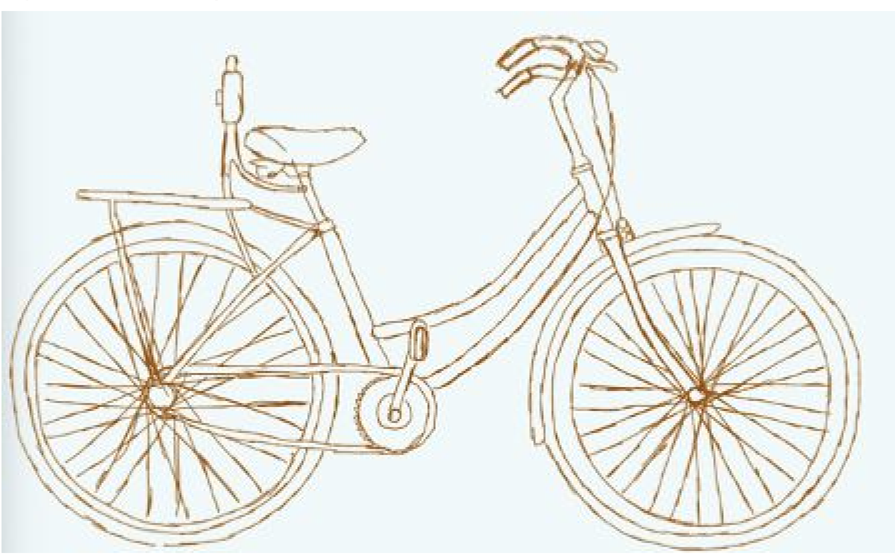


Figure 5 - initial sketch of our bike

Figure 5 - Morphological Comparison bikes

[1]

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- Frame Size 57cm: 31" to 38" Inside Leg (79cm to 96cm)

GEARS	8
FRAME SIZE	Frame Size 57cm: 31" to 38" Inside Leg (79cm to 96cm)
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WARRANTY	10 years on frame and fork
INCLUDING	lock, lights, carrier, stand, bell, pump, puncture resistant tyres
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[2]

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