Low Step Bike Mechanical Design 2 Group Report

Group 29

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Project Brief

Our project aims were to design a low step bicycle using Fusion 360 software. The primary objective is to create a bicycle that offers easy accessibility and comfort, particularly for users with mobility issues or those who prefer a more convenient mounting and dismounting experience. A low step bike is one that has a frame with a lower height of top and down tube to improve accessibility. The design will prioritise safety, functionality, and aesthetics, considering factors such as frame geometry, materials, and assembly methods.

We used Fusion 360 to design the components separately and then joined them later to get the whole 3D model bike. We considered technical requirements extracted from the House of Quality and concepts from Morphological Analysis. A few conceptual ideas were made first which would be improved later to the final design. Finaly our group had to make an online presentation regarding the low step bike design and discussing about the main aspects of this project. The project outcome was a well-designed low step bicycle that offers enhanced accessibility and usability, showcasing Fusion 360's capabilities.

Gantt Chart

The team used a Gantt Chart to distribute tasks to optimise overall progress. This was done to suit individual member’s strengths and ensured that every team member was involved in the project, while providing a balanced workload for the whole group. Each task was then assigned a start and end date, this provided a deadline for each task. This would be used as a guide to finish the project on time, as the Gantt Chart keeps track of which tasks are incomplete and gives accountability to each group member to complete their allocated tasks.

The Gantt Chart that the team originally designed is below in Figure 1.1, this is what the team tried to work from the beginning of the project.

Figure 1.1 - First half of Initial Gantt Chart

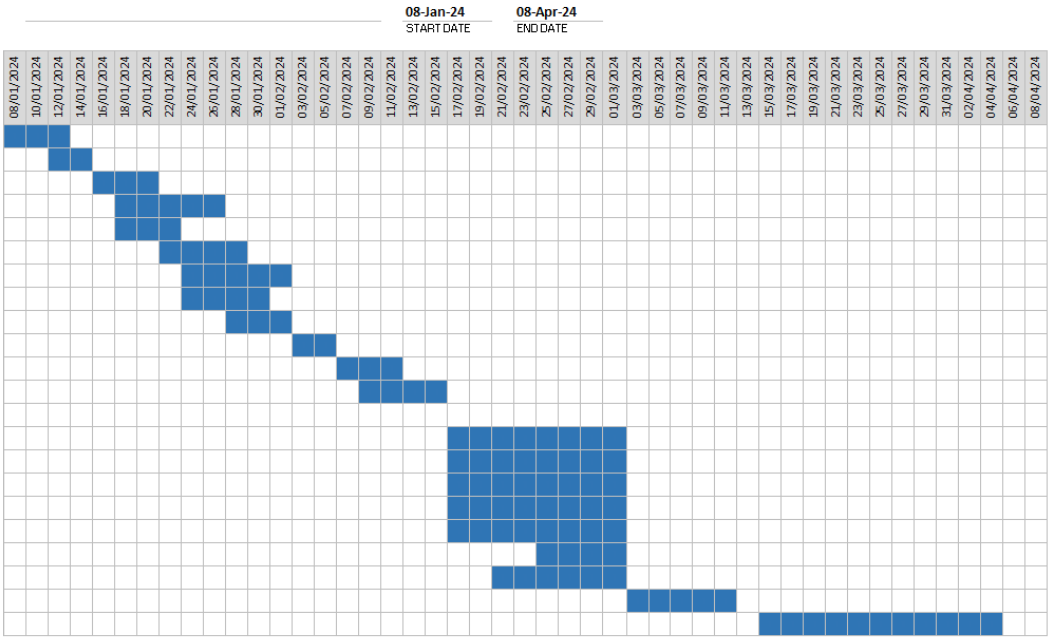


Figure 1.2 – Second half of Initial Gantt Chart

As the project progressed issues in certain tasks arose and completion dates slightly differed to what was originally planned. This prompted the Gantt Chart to be adapted to account for these delays which occur in all engineering projects, this ensured the project was completed on time while giving team members some flexibility to complete tasks. The adapted Gantt Chart displays the actual time taken for each task to be completed compared to the intended original end date, this is shown below in Figure 2. The adapted Gantt Chart also shows how some of the allocated tasks were completed by different team members than had been originally planned this was done to ensure the project was completed on time as some tasks were falling behind schedule.

Figure 2.1 – First half of adapted Gantt Chart

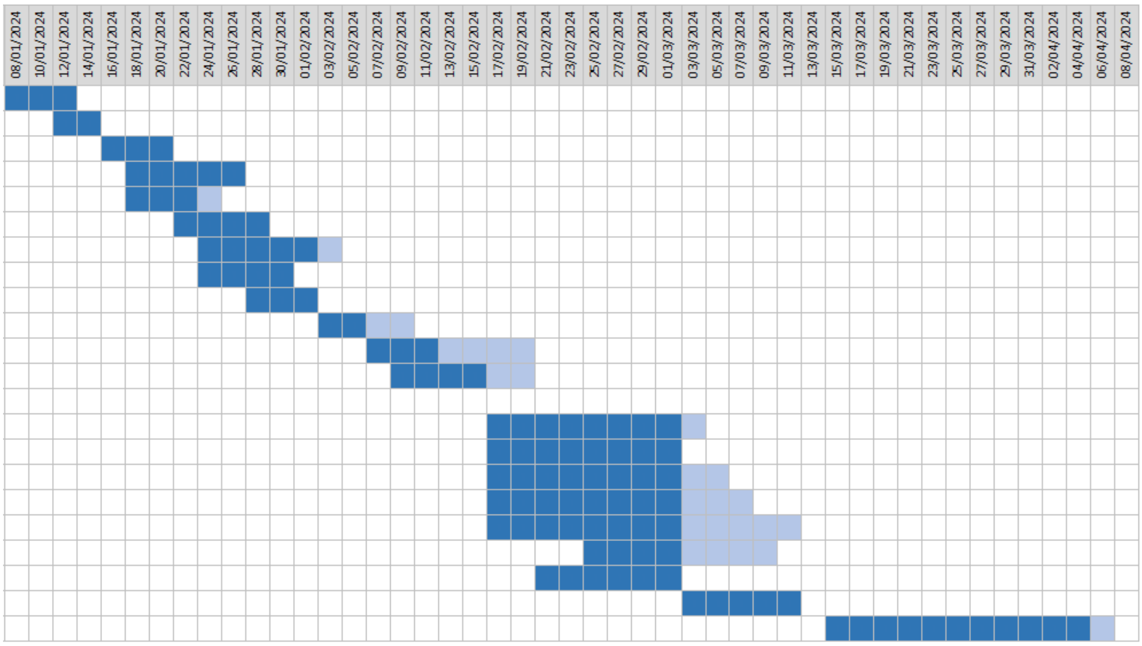


Figure 2.2 – Second half of adapted Gantt Chart

Current Market Analysis

Low-step bikes have a niche market since they are designed so that you can easily get on or off the bike which is useful mainly for people who frequently stop while riding a bike or people who have hip or knee problems. These bikes are aimed mainly at older people ages 40 or above since according to our research arthritis is most common for people of this age range with 350 million people suffering from arthritis globally so low-step bikes are more suitable for them as it is easier to get on and off the bike. From our research, we found that low-step bikes have a price range of between £300 to £800 and can vary depending on the brand with the Specialised Sirrus, Raleigh Sherwood and pioneer bikes being some examples of low-step bikes currently on the market.

Figure 3.1 – Raleigh Sherwood low-step bike

Figure 3.2 – Specialised Sirrus low-step bike

Compare with Competitors

The Specialised Sirrus and Raleigh Sherwood bikes are two of the many competitors fighting for market dominance in the low-step bike niche. Their visually pleasing look and perceived reliability come at a high price, even if these bikes may have an identical design with minor variations. But despite being low frame bikes, those with knee injuries may still find it difficult to ride them, which makes them less than ideal for this group of people. This is a significant disadvantage.

Our low-step bike's main goal is to improve reliability and meet the needs of people who have knee injuries. We will consider the design of the pedals and wheels, among other minor adjustments, to accomplish this. But one big change that distinguishes our design from others is the addition of specialised gears that make it more accessible for people with knee injuries.

User Requirements

The findings from the current market analysis identified the key user requirements for our target market of 40+ adults with a knee injury. The key customer requirements found are the following:

- Easy mount and dismount (without lifting leg)
- Safety when riding (Balance)
- Smooth ride (low impact)
- Reasonable price structure

Accessibility, being able to get on and off the bike easily without aggravating an existing knee injury, is evidently the most important user requirement as it is the reason for purchasing a low step bike. The low step bike is specifically designed to have a frame with a lower height than a traditional standard bike thus being the most important design aspect to consider.

Safety when riding is also a key user requirement this is because the target market for this bike is 40+ with an existing injury meaning the user is already vulnerable. This shows safety is very important and the team must consider a balanced and safe design to protect the user.

Smooth ride is a user requirement as the user has an existing injury. This means the team will have to consider a design to keep the impact on the user at a minimum. Implementing an effective suspension system is vital to minimizing the impact transferred to the user.

A reasonable price structure is identified as being important to the user in the market analysis. When researching competitors on the market, we found that there is a gap in the market for mid-range bikes as the market is full of low and high range bikes.

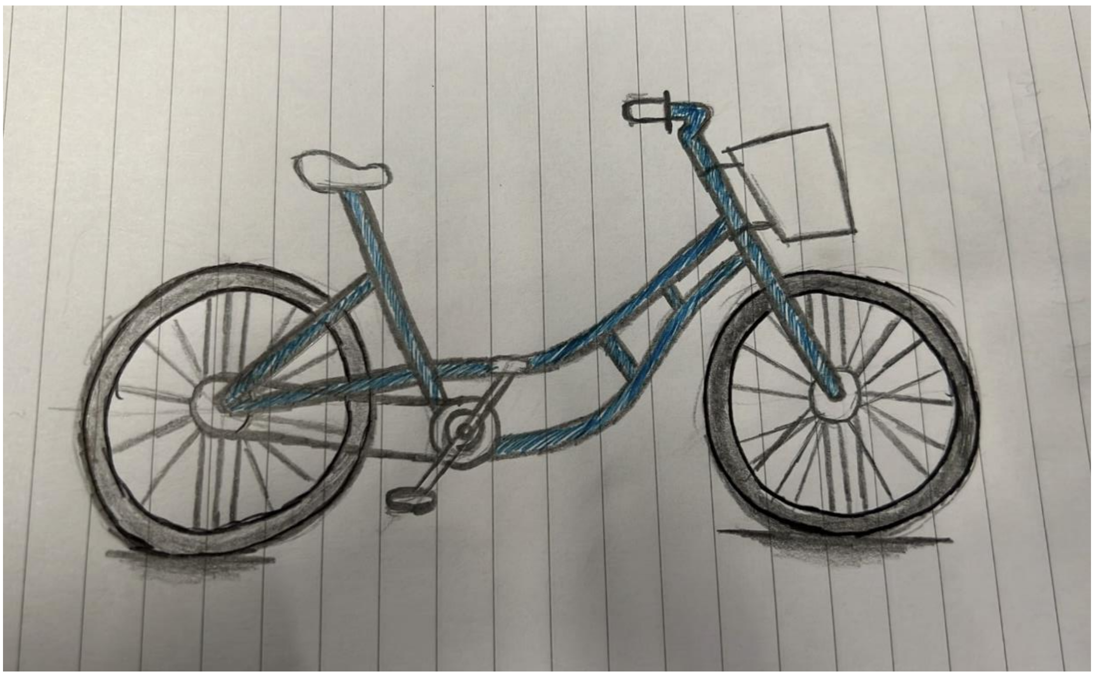
Conceptual Designs

With the overview of the project's main specifications, the team started working to develop initial ideas for the low step bike. We used a morphological analysis table to categorise the different combinations that could complete the desired design. We first made a list of the features for the bike: brake system, suspension type, added features, wheel type, frame material, storage gear system, frame structure, gear shifters, low step frame design, number of gears, tire dimensions and pedal type. For each of the features, several concepts were developed by using different combinations of components from the table. Some of these combinations would conflict and would not be practical for the final design but these designs are helpful as we can take the best parts from each design in order to refine for the final design.

Using the morphological analysis table, we were able to generate two sketches of a low step bike and we tried to make sure that both ideas were different from each other in most of its features in order to ensure enough diversity.

Morphological Analysis Table

Feature	1	2	3	4
Brake System	Disc Brakes	Rim Brakes		
Suspension Type	Coil Springs	Elastomer	Air springs	
Added features	Mud guards	Front and Rear lights	Stand	



Wheel Type	Road (Smooth)	Commuter (wider for comfort)	Cyclocross (Suitable rural roads.)	Hybrid (Road and Mountain crossover)
Frame Material	Carbon Fibre	Steel	Titanium	Aluminium
Storage	Basket	Rear Placeholder	Water bottle holder	Saddle bag
Gear System	Derailleur Gear	Single Speed	Hub Gears	
Frame Structure	Curved Top Tube	Connecting Top and Bottom Tube	No Top Tube	
Gear Shifters	Thumb Shifter	Grip Shifter	Trigger Shifter	
Low Step Frame Design	No Top Tube (Thick Bottom Tube only)	Low and curved top Tube	Connection Rod to Bottom Tube	Perpendicular bend in bottom Tube
No of gears	20	7	14	
Tire Dimensions	700c	26 inches	27.5 inches	
Pedal Type	Clipped	Unclipped	Gripped	

Figure 4 – Morphological Analysis

These are the designs we have based off the concepts found in the morphological analysis. These were later improved for the final design.

Figure 5.1 – Concept 1

For concept 1, we have designed a bike which will be used to cycle around on road surfaces as we can see it has road tires. One of its main points are the basket fixed at the front. The main frame has a low top tube connected subtly to the bottom tube while minimizing cross-sectional area which makes the whole weight of the bike lighter therefore easier for the user to ride. This design also uses unclipped pedals, disk brakes, twenty-six inches diameter tires and a carbon fibre frame all taken from the morphological analysis above.

Figure 5.2 – Concept 2

For concept 2, we came up with a low step bike which is adaptable to any environment. The material chosen is steel which will make the design more solid and shock resistant. Other modifications we made were the additions of the water bottle hanger and mudguards to minimise the amount of mud sprayed around when conditions are wet. Hooked pedals were implemented in this design to increase safety. This concept uses thicker tires to increase grip and be suitable for use in any urban terrain.

Ergonomic Aspect

The term ergonomic can be used as a term for a state of physical and mental wellbeing but also the absence of pain or similar nuisance. Ergonomic factors need to be taken into consideration during the design of our project. The padding of the handlebar is one option for making a bike ride more comfortable.

Figure 6.1 – Types of handlebars researched

Wheels are one among the most important parts of the bike. Type and sizes of the tires can contribute to the ergonomic aspect as well. The design for the bicycle seat is important also to ensure the comfort and safety of the rider.

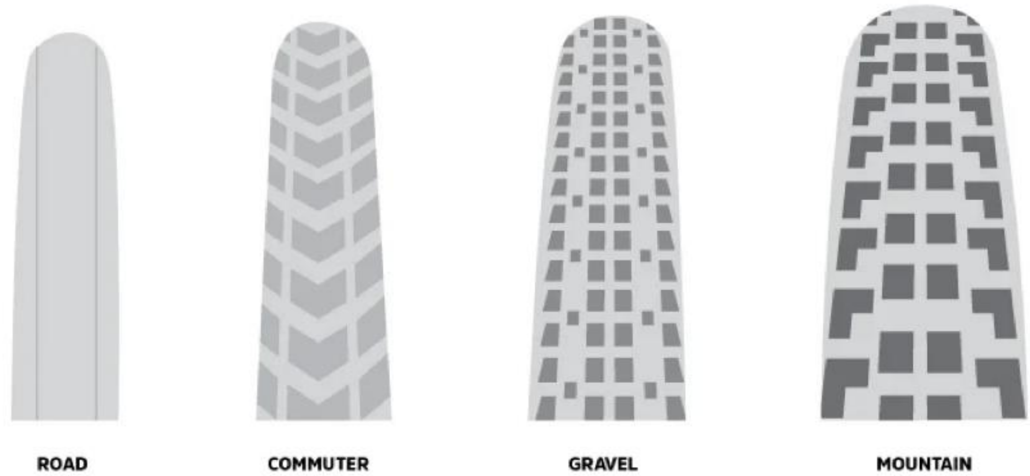


Figure 6.2 – Types of tyres researched

The principles of ergonomic design for the low step bike are considered in three levels are determined below:

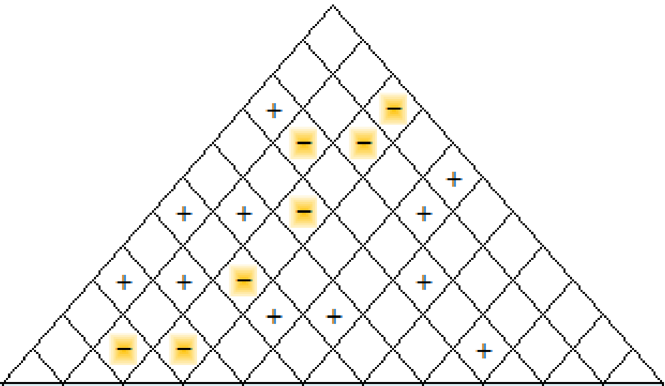
1. Bike must be safe while the rider is in contact.
2. Bike must not cause harmful effects on the user over longer periods.
3. Bike must be physically comfortable; it should not need too much effort.

Quality Function Deployment (QFD)

Correlations	
Positive	+
Negative	−
No Correlation	

Relationships	
Strong	●
Moderate	○
Weak	▽

Direction of Improvement	
Maximize	▲
Target	◇
Minimize	▼



Row #	Weight Chart	Relative Weight	Customer Importance	Maximum Relationship	Customer Requirements (Explicit and Implicit) / Functional Requirements	1 Height of Low Step Bar (cm)	2 Maximum Load on Low Step Bar (kN)	3 Weight (kg)	4 Wheel Diameter (inches)	5 Expected Lifespan (years)	6 Overall Height of the Bike (m)	7 Young's Modulus of frame material (Pa)	8 Seat Dimensions (mm)	9 Handlebar Dimensions (cm)	10 Size of Brakes (mm)	11 Number of Gears	Our Product	Competitor #1: Raleigh Sherwood	Competitor #2: Specialized Sirrus X 2.0	Row #
					Direction of Improvement	▼	▲	▼	◇	▲	◇	▲	◇	◇	▲	◇				
1	IIIIII	13%	9	9	Safe	▽	●		▽	○		○		▽	●		4	2	4	1
2	IIIIII	13%	9	9	Low Top/ Bottom Tube	●	○	●									4	2	2	2
3	II	6%	4	3	Aesthetic	○			○		▽		○	○	▽		2	5	4	3
4	IIIII	11%	8	9	Affordable		○	▽	▽	●		▽		▽	○	○	4	4	2	4
5	IIII	10%	7	9	Ergonomic	○	○				○		●	○			3	4	2	5
6	IIIII	11%	8	9	Reliable / Durability	○	●		○	●		●			○	○	4	2	4	6
7	IIIII	11%	8	9	Stability / Balance	▽	○	▽	○	○	▽		○	●	○	○	3	3	4	7
8	IIII	10%	7	3	Adjustable Components	▽					○		○	○			3	3	3	8
9	IIIII	11%	8	3	User Friendly	○	○			▽	○		○	○	▽		5	4	2	9
10	II	6%	4	3	Storage			○					▽				2	4	1	#
					Max Relationship	9	9	9	3	9	3	9	9	9	9	3				
					Technical Importance Rating	258	379	151	107	282	108	149	206	232	229	100				
					Relative Weight	12%	17%	7%	5%	13%	5%	7%	9%	11%	10%	5%				

Customer Competitive Assesment

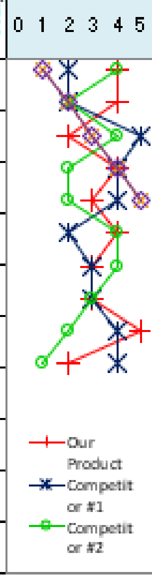


Figure 7.1 – House of Quality

A House of quality for a low step bicycle was constructed to help consider the most important design aspects and incorporate those into the final design, as can be seen in Figure 7.1. This would help consider the needs of the customer and ensure the product designed suits the target market.

The House of Quality was produced by creating a list of customer requirements and ranking them based on importance to the target market which was the 40+ age category. As seen in Figure 7.2; each customer requirement has a rating based on the customer importance and relationship with functional requirements. The customer requirements taken from the House of Quality were ranked, with the most important being Safe and Low Top/ Bottom Tube, as they both have a Relative Weight of 13%, this was followed by Affordable, Reliable/ Durability, Stability/ Balance with 11%, Ergonomic and Adjustable Components with 10%, this leaves Storage and Aesthetic being the least important with just 6%. This is a clear indication that Safe and Low Top/Bottom Tube are the customer requirements that should be taken into consideration the most.

Row #	Weight Chart	Relative Weight	Customer Importance	Maximum Relationship	Customer Requirements (Explicit and Implicit) / Functional Requirements
1	IIIIII	13%	9	9	Safe
2	IIIIII	13%	9	9	Low Top/ Bottom Tube
3	II	6%	4	3	Aesthetic
4	IIIII	11%	8	9	Affordable
5	IIII	10%	7	9	Ergonomic
6	IIIII	11%	8	9	Reliable / Durability
7	IIIII	11%	8	9	Stability / Balance
8	IIII	10%	7	3	Adjustable Components
9	IIIII	11%	8	3	User Friendly
10	II	6%	4	3	Storage

Figure 7.2 – Customer requirements from HoQ

A list of functional requirements is found across the top and each requirement is assigned a symbol on whether this variable is maximised, minimised, or fit to target. An example from the House of Quality was the Maximum Load of Low Step Bar (N) was to be maximised. This information was used to determine the correlation between the functional requirements, found at the top of the House of Quality, this is seen in Figure 7.1. An example from the table in Figure 4.1 is minimising Weight (kg) having a negative correlation with maximising Size of Brakes (mm).

The relationships between customer requirements and functional requirements were then recorded and given a relationship of strong, moderate, weak, or nothing. These ratings would then be used to calculate the technical importance of each functional requirement. The importance ratings are vital when there are conflicting functional requirements as it highlights which requirement should be prioritised based on their rating to ensure that design choices made will maximise customer satisfaction. When analysing the House of Quality, the functional requirement maximising Maximum Load of Low Step Bar (N) has a negative correlation with minimising weight (kg), since Maximum Load of Low Step Bar has a higher technical importance rating (17%), than that of weight (kg) (7%), it must be prioritised in the design.

The technical importance ratings rank the functional requirements accordingly clearly showing which requirements should be prioritised based on their importance to the customer. The three functional requirements with the highest technical importance were Maximum Load of Low Step Bar (N) (17%), Expected Lifespan (years) (13%) and Height of Low Step Bar (cm) (12%). These functional requirements were prioritised in design considerations when refining the conceptual designs to create the final design. The three functional requirements with the lowest technical importance were Wheel Diameter (inches) (5%), Overall Height of the Bike (m) (5%) and Number of Gears (5%).

Max Relationship	9	9	9	3	9	3	9	9	9	9	3
Technical Importance Rating	258	379	151	107	282	108	149	206	232	229	100
Relative Weight	12%	17%	7%	5%	13%	5%	7%	9%	11%	10%	5%

Figure 7.3 – Technical Importance Ratings taken from HoQ

Customer requirements listed on the HoQ have a rating from 1-5, to compare our product against the market competitors, the competitors were Raleigh Sherwood and Specialized Sirrus X 2.0. This gave a good indication on how our bike would be received by the target market compared to two of the market leaders. A diagram was produced to display the comparison between the three bikes, this clearly shows the strengths and weaknesses in the design. Our design has the highest rating for customer requirement of user-friendly (5) compared to our competitors, which had (4) and (2) respectively, this gives the team a clear advantage over the market to advertise. Maximum user-friendly rating for our design was due to our design having no top tube making the bike accessible for all users. A main weakness identified when comparing our design to market competitors was in the customer requirement aesthetics. Our product has a rating of (2) compared to the competitors with (5) and (4) respectively, this gives the market leaders a clear advantage over our design. However, as identified in the analysis of customer requirements aesthetics ranked as the least important customer requirement with just 6%. This design aspect was neglected to prioritize more important customer requirements which would make our bike overall more appealing to the target market.

Detailed Design

Initial Design

Figure 8 - Initial CAD model.

The bike above in Figure 7.1 shows the model produced at the time of the mock presentation, while the bike below shows the final CAD model. The final model improved upon the prior through gripping on the handlebars, tyres, suspension, proportioning and dimensional changes.

Final Design

Figure 9.1 – Final CAD model

The saddle was improved to be more ergonomic by changing the shape to be more streamlined and textured to make the saddle more comfortable for the user. The dimensions of the handlebars were also changed to improve ergonomics and safety. This was done by increasing the thickness of the handlebars to reduce the chances of a fracture. The diameter of the handlebars was also increased to make the bike more ergonomic as it makes the user be able to sit in a neutral position. The gripping of the handlebars was improved by increasing the area over which it covers to leave a less concentrated section of wear.

Dimensions:

Height of Bike: 1.02m

Length of Bike: 1.835m

Height of Low Step Bar (Where Bottom Tube connects to Seat Tube): 0.319m

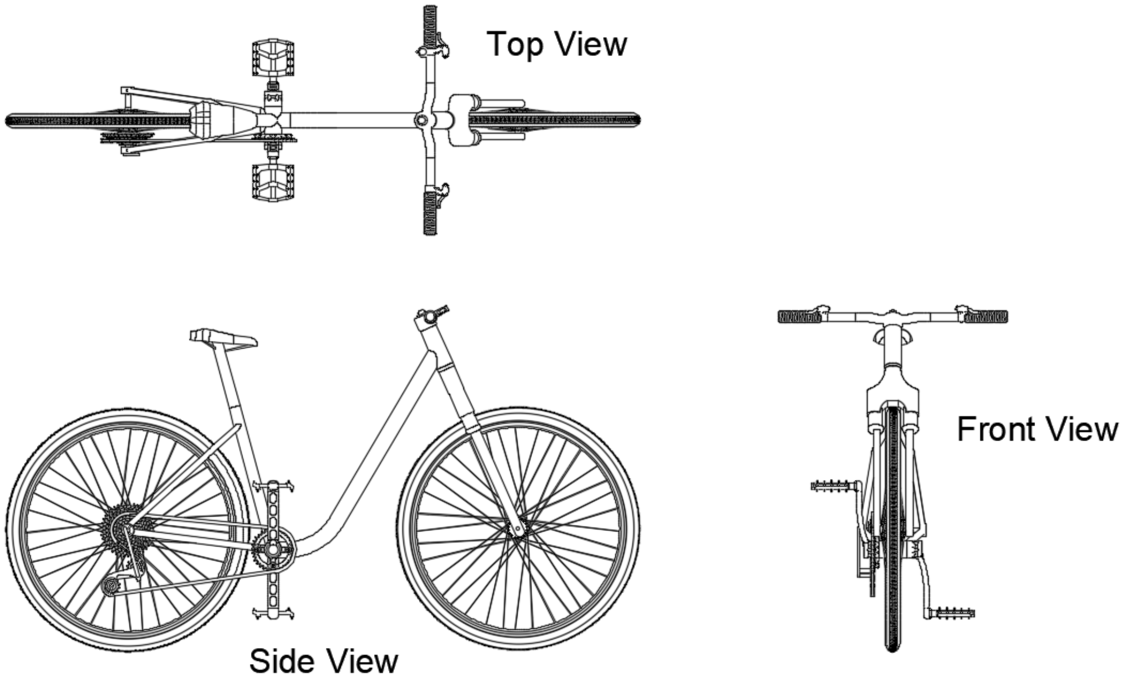


Figure 9.2 – Final Design CAD model

Frame

As seen in Figure 9.3 the frame is of an unconventional shape as it has no top tube and is made from Aluminium Alloy. The frame is a vital component as it supports the user's weight and connects all the components of the bike together. This design decision was made to make the frame height as low as possible for the user in the target market (40+ with a knee injury), this was identified as 2nd most important functional requirement in the House of Quality. The frame design with no top tube is in the Morphological Analysis table, this initial concept was improved throughout the design process to get to the final model to ensure safety when only having a bottom tube.

Figure 9.3 –Final CAD model of low step frame

Suspension

As the exploded view below (Figure 10.2) of the front frame shows, the bike has a front coil spring suspension. Coil springs were chosen as suspension inside the front fork as it provides stability and improves shock absorption causing less impact on the user who already has a knee injury. Coil springs are in the Morphological Analysis table this concept has been carried through from the first initial designs to the final model.

Handlebars

The handlebars are an adaptation of a riser handlebars design to improve ergonomics, allowing the user to be able to sit upright comfortably with minimal pressure on their knee injury. Ergonomics is a customer requirement that was identified in the House of Quality, so this design feature is something to be considered. The handlebars have also been designed with gripping to maximise comfort and improve safety which is also a customer required listed in the House of Quality.

Gear Changer

The gear changer is a single flick thumb shifter. The gear changer doesn't have numbers on it, but this isn't required as there is only one, flicking up will increase the gear ratio and down will decrease it. The thumb shifter is on the Morphological Analysis table and has remained in the final model from the initial designs as it is the most practical.

Wheels

The wheel is designed like a normal bicycle wheel so that the tyre can be removed and put on with tyre levers so that the user can access the inner tube. The tyres are Hybrid Tyres so they can be used in road and other pedestrian terrains, this meets the customer requirement of durability as hybrid tyres improve lifespan in all terrains. The tyres were chosen to be 700C as this is a standard size of tyre meaning they can be easily replaced by a user if they break, this concept is in the Morphological Analysis table and made it through all design stages. This will also decrease the chance of a puncture which was identified as the failure mode with the highest risk in the Failure Mode Analysis.

Gears

There are 8 gears on the rear ranging from 13 teeth to 41 teeth increasing by 4 each and a singular front gear with 33 teeth. This choice was based off real bikes on the current market. It may reduce the options available, but it removes most issues with changing gears and simplifies the controls.

Figure 9.4 – Final CAD model of rear gears

Chain and Inner Tubes

The inner tubes and chain of our low step bicycle are bought like standard components as they are common components which the consumer would need to replace and maintain many times over the bike's life.

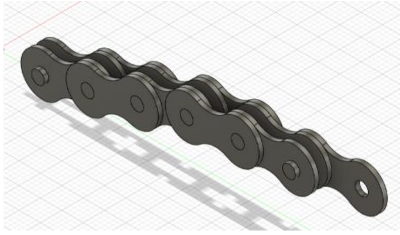


Figure 9.5 – Final CAD model of Chain

Saddle

The Saddle was designed to be ergonomic and maximise stability for the user. This was done by creating a seat with a lower depth towards the centre, the saddle also decreases in diameter towards the front this is to reduce material and ensure the injured leg is comfortable and not aggravated.

Figure 9.6 – Final CAD model of Saddle

Pedals

The pedals are designed to maximise grip in the interest of user safety (Figure 10.1).
Gripped pedals were incorporated in the final design after being in the Morphological Analysis, this was a concept kept as it increases safety as it reduces the chance of the rider losing grip of the pedals. The pedals are made from Steel Alloy as this is a material with a high Ultimate Tensile Strength (670MPa) this reduces the chance of a pedal fracture which is a failure identified in the Failure Mode Analysis.

Additional CAD Images

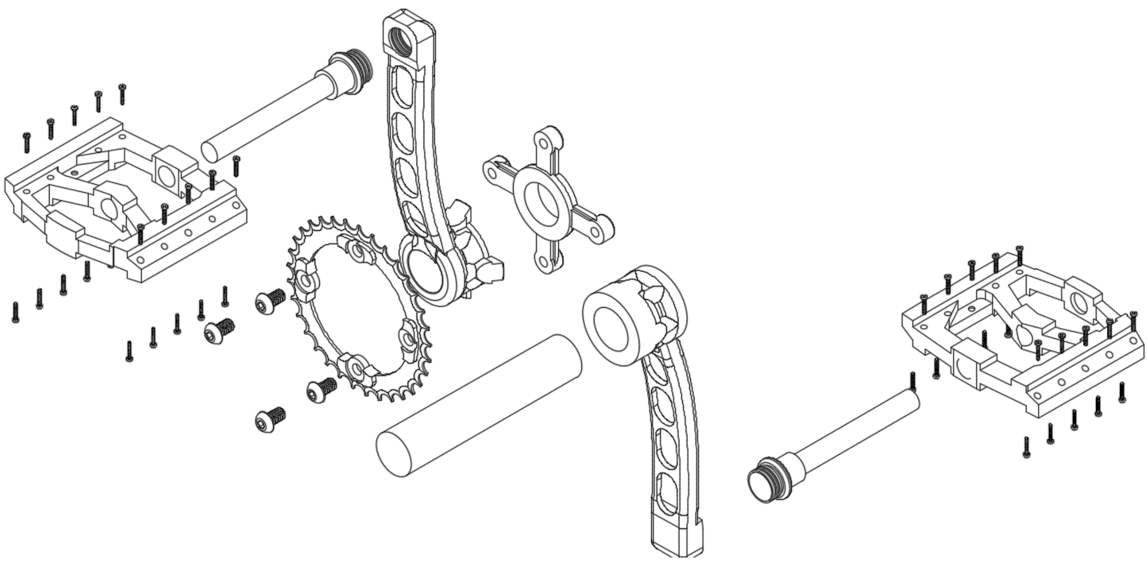


Figure 10.1 – Exploded view of pedals

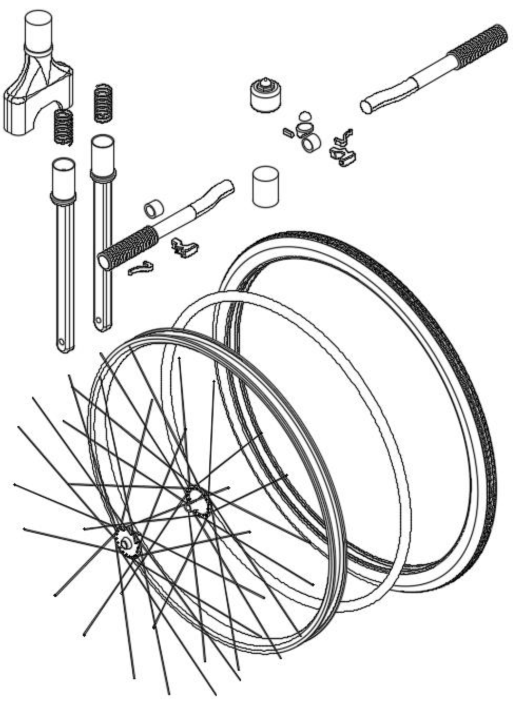


Figure 10.2 – Exploded view of front fork with suspension

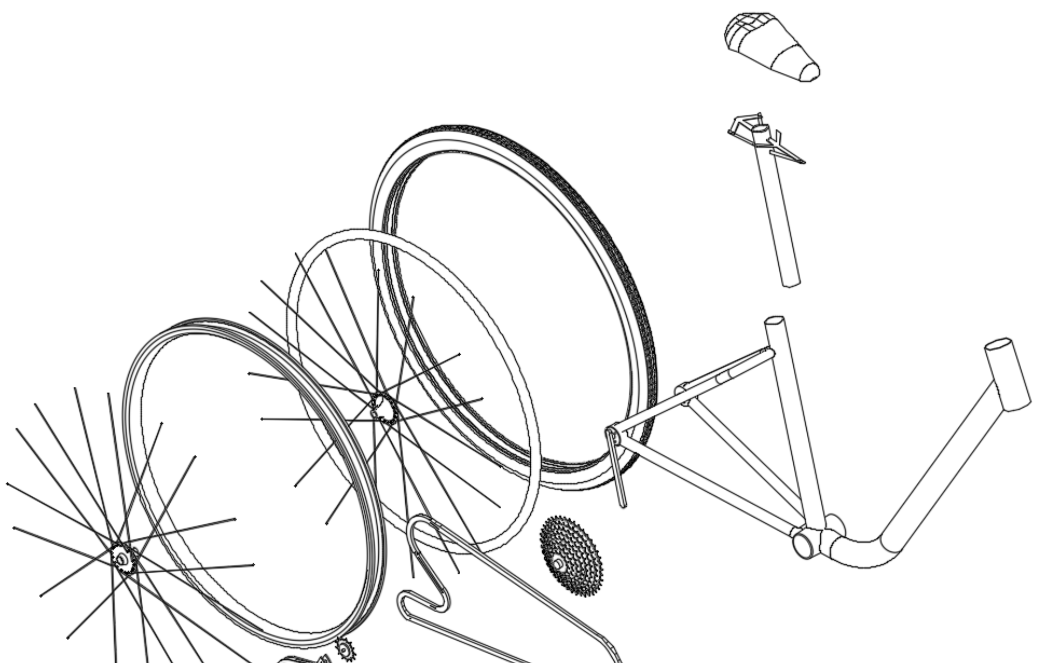


Figure 10.3 – Exploded view of rear components

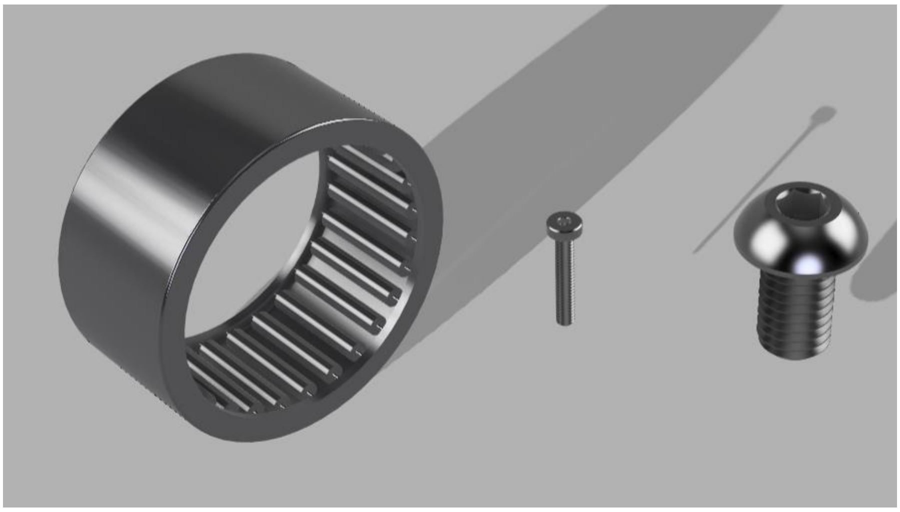


Figure 10.4- Bearings and screws used in pedals.

The standard component used are:

1) 5905k578 needle roller bearing X1

2) 92855a841 18-8 stainless-steel low-profile socket head screw X40

3) 91239a417 Button head Hex drive screw X4

The bearings (1) are used in the frame for the pedal shaft.
The first type of screws (2) are used in the pedals to provide solid grip to the user.
The second type of screws (3) are used in the pedals to keep the single gear in place, this also allows it to be removed to be repaired or replaced.

Overall, the total cost of these parts equals £85.21, this is quite expensive, however this pricing is for public purchase and for small batches, this would be largely reduced for a company purchasing in bulk.

Material Selection

The frame of the low step bike was chosen to be made of Aluminium Alloy 6061. This design choice was made as the material chosen needed to be strong as there is no top tube in the frame. In the house of Quality maximising Young's Modulus of the frame (Pa) is a Functional Requirement for the bike. Aluminium Alloy 6061 was selected as it has a Young's Modulus of 69GPa. Aluminium alloy 6061 also has an ultimate tensile strength of around 260MPa which is vital to the design as a frame fracture was identified as a possible failure in the Failure Mode Analysis.

The gears and pedals were chosen to be made from steel alloy. Steel alloy was chosen as it is a reliable material that is used in many other bikes on the market. Steel alloy has a Young's Modulus of around 200GPa and an ultimate tensile strength of 670MPa, this is useful for the gears and pedals as it reduces the chance of a fracture.

Stress Calculations

Biggest Axial Load Scenario:
Stress Calculations were done using a worst-case scenario to ensure the bike was safe for all users.

Radius of Bottom Tube: 22.5mm
Thickness of Bottom Tube: 3mm
Weight of 6'10" obese person: 175kg
Weight of baggage carried by person (backpack): 20kg.

Calculate cross-sectional area:

$$A = \pi r^2$$

$$A = \pi\,(22.5^2 - 19.5^2)$$

$$A = 395.841\text{mm}^2$$

Calculate Axial Force:

$$F = mg$$

$$F = (175 + 20) \times 9.81$$

$$F = 1912.95N$$

Calculate Axial Stress:

$$\sigma = F/A$$

$$\sigma = 1912.95/\ 395.841 \times 10^{-6}$$

$$\sigma = 4832622.189Pa$$

$$\sigma = 4.8MPa \text{ (rounded to 2 s.f)}$$

The material of the bottom tube is Aluminium Alloy 6061 which has an ultimate tensile strength or around 260MPa. This is considerably larger than the calculated value above, this shows that the frame is clearly strong enough to withstand the loads applied to the bottom tube despite having no top tube support. This calculation only considers the axial stress applied on the frame and does not consider the bending, torsional and fatigue stresses. However, when taking average values of these additional stresses only add to around 35MPa which is still well below the ultimate tensile stress when added with the axial stress.

Failure Mode Analysis

The team constructed a Failure Mode Analysis table to consider the possible failures within our design. This is a useful tool as is it identifies failures and ranks how frequently they occur and how severe this would be to the bike and the user.

Function	Failure Mode	Effects of Failure	S	Causes of Failure	O	Design Controls	D	RPN	CRIT	Recommended Actions
Chain/ Gears	Tooth wear	Issues changing gear	3	Overuse, lack of lubrication	3	Compatible Chainring teeth and Chain	2	18	9	Lubricate often, clear instructions on how to lubricate
	Skipping chain rotation	Loss of mechanical power	4	Worn chain, worn cassette	2	Using High quality steel	2	16	8	Replace chain if teeth are broken
	Chain Fracture	Inefficient transmission, Snapped Chain	8	Dirt in chain, Overuse, Lack of lubrication	1	Select durable material with high yield strength	1	8	8	Wash and lubricate
Frame	Fracture	Instability, User can fall	9	Impact, Corrosion	1	Select durable material with high yield strength	1	9	9	Safe Storage, sensible usage
	Loose Saddle	Instability, Poor ergonomics	2	Overuse, Corrosion within fastening	2	Using tight fit bolts	2	8	4	Check before use, Tighten seat regularly
Brakes	Wearing of brake pads	Inefficient stopping power, rider accident	6	Overuse,	4	Bedding-in procedure shown in user manual	3	72	24	Check brakes regularly
	Loose brakes	Poor control over the brakes	3	Overuse, Impact	3	Tight fit with brake components	2	18	9	Tighten brakes
Pedals	Fracture, Fatigue	Difficult for user to pedal, lack of grip	8	Overuse, Impact	2	Pedal Geometry designed to improve strength	2	32	16	Replace pedal
Wheels	Puncture	Instability, Damages inner tubing and wheels,	9	Overuse, Use in rough terrain	7	Hybrid Tyres with puncture resistant layer in lining	2	126	63	Check wheels regularly, carry repair kit
	Wearing of Tread	Instability, Inefficient transmission	3	Overuse,	2	Hybrid Tyres tread pattern for to road or off-road terrain	3	18	6	Replace when tread depth is too low
Suspension	Fatigue	Instability, Risk of injury	4	Overuse	2	Select durable material with high yield strength (Steel)	2	16	8	Replace Suspension

Figure 11 – Failure Mode Analysis Table

The table lists a component in the low step bike and then goes through the possible failure modes associated with the specified component. Effect of Failure is the following column, this describes what this failure would do to the bike. An example from the table is in Chain with the Failure Mode being Tooth Wear the Effect of Failure is Issues Changing Gear, this is because the tooth wear would lead to skipping chain rotations giving crunching gear changes. Each of these effects of Failure is then assigned a Severity rating (S) from 1- 10, Issues Changing Gear has a severity rating of 3, as this failure would not put the user in serious danger and would not effect of the structural integrity of the bike.

The next Column states the Causes of Failure for each failure mode, from the table for Tooth Wear this is Overuse and Lack of Lubrication. Each of these causes of failure is then given an Occurrence rating (O) from 1-10, Tooth Wear has an Occurrence rating of 3, this shows that this mode does occur but not frequently.

Design Controls state the actions taken in the design process to prevent these failure modes from occurring. For the failure mode of Tooth Wear the design control the team implemented was compatible chainring teeth and chain, this ensured that the teeth would fit together effectively without causing immediate wear. These design controls have a Detection rating (D) from 1-10, this rating shows how effective the design control is as it measures how easily the failure is detected with specified design control. From the table design control compatible chainring teeth and chain has a Detection rating of 2, this shows that Tooth wear is difficult to detect with our design control.

RPN is the Risk Priority Number which is the product of Severity (S), Occurrence (O) and Detectability (D). This number represents the overall risk associated with the specific failure mode. RPN clearly shows which failure mode presents the biggest risk. From the table, the Failure Mode of a Puncture has the highest RPN number (126), this Failure Mode clearly presents the greatest risk. A loose saddle and a chain fracture present the least risk with the lowest RPN number (8).

CRIT is the Criticality number which is the product of Severity (S) and Occurrence (O). This number measures the risk based on just the Severity and Occurrence and does not factor the Detectability in. Seeing the difference between the RPN and CRIT shows how effective the design control is for reducing the risk presented. A puncture has the highest CRIT number (63), this shows that a puncture presents the biggest critical issue. A loose saddle has the lowest CRIT number (4), this presents the least critical issue.

Recommended Actions are the strategies implemented to alleviate the identified risks. The recommended actions improve the performance and reduce the chances of a failure occurring. An example of Recommended Actions from the table for Tooth Wear is Lubricate often and Clear instructions on how to lubricate the chain.

Costing

Part	Quantity (Per bike)	Unit price(£)	Total price (Per 1000 bikes)(£)
Handles	1	32.3	32300
Wheels	2	63.3	126600
Tires	2	39	78000
Seat	1	21.3	21300
Pedals	2	26.6	53200
Frame	1	100	100000
Gears	9	18	162000
Brakes	1	22.4	22400
Suspensions	1	21	21000
Gear back shifter	1	14	14000

Figure 12 – Costing Table

The team created a costing table to evaluate the cost of the components in the bike. This was done by evaluating parts on the current market. These prices on the table are slightly inflated as this was based on the individual part prices. However, when buying in large quantities this cost would be less than the prices listed on the table, as suppliers would offer better prices when placing an order in large quantities. Some of the parts on this bike were specifically designed and so are of a complex geometry, this means the parts are not standard and therefore will be more expensive to source and manufacture.

Project Evaluation

The Detailed Design developed throughout this project was made to meet the user requirements. When comparing the detailed design to the user requirements the detailed design is clear that the design does meet the user requirements.

The design of the low step frame having no top tube clearly meets the user requirement of an easy mount/ dismount. Our design took careful consideration into minimizing the height of the low step bar to allow the user to use the bike comfortably without risk of injury.
The user requirement of safety met as it was greatly considered throughout the design process. This was very important when designing the frame as it is specifically designed to accommodate for good balance with a symmetrical rear geometry. The dimensions and material selection of the frame ensure safety as the maximum stress applied is under half of the ultimate tensile strength of Aluminium Alloy 6061.

A low impact for the user is another user requirement that was taken into consideration during the design process. The team tackled this by implementing coil suspension, this reduces the impact from the front fork of the bike. However, this could be further improved by adding more suspension into the design to create a smoother ride for the user.

Overall, the team performed well throughout the project and completed the tasks to a high standard. The team excelled incorporating aspects from the Morphological Analysis table and priorities identified in the House of Quality into the final model. We also displayed good teamwork to complete the CAD model to such a high standard, this involved team members helping each other to complete different components before they were all fitted together.

However, the team could've been better with communication as some members did not make equal contributions leading to an unbalanced workload. If we were to do this project again regular in-person meetings and a specified leader from the start of the project would improve the outcome of the project as there would be more accountability and better time keeping throughout the team.

Analysis of group work meetings, file exchange, planning, leadership

Analysing the group work dynamics in our low step bike design project reveals a collaborative effort marked by effective communication, efficient file exchange and precise planning. Our regular meetings served as crucial checkpoints, providing opportunities to discuss progress, address challenges, and align our efforts towards shared goals. Through platforms like WhatsApp and email, we easily exchanged files, ensuring that everyone had access to the latest updates and resources. Our planning process was characterised with the aim of our tasks carefully delegated and timelines established. Additionally, leadership was a quality that lacked within our team, not appointing an overall leader for the entire project would've helped, however a couple of individuals in the team did step forward to lead the team to completing the project on time and to a high standard. Overall, from the elements stated, we were able to cooperate and create a productive environment, driving our low step bike design project towards success.