MOTORIZED 2WHEELE-SCOOTER WITH GPS TRACKING

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Abstract - The present work intends to study and create a solution to be used as a means of transportation adapted to the metropolis environment. This solution lies in projecting and building a prototype of an electrically assisted power cycle, mainly directed to be used around the "Lastmile" concept.

It was made a survey to perceive the legislation that concerns this type of vehicle, this was in order to understand the several different classifications that it can have and what were our constraints regarding the law. The market was also researched which showed that e-bike sales have experienced massive growth in the last years.

The components of bicycles and electrical bicycles were studied and compared, this way we could do a correct and wise choice of components to be used in the project. Since the market already presents several different solutions in terms of this concept, it was made a study regarding some of the market available models, considering its advantages and disadvantages.

Prior to the creation of the design, we established some main requirements, these constitute the points with major importance concerning a vehicle clefor this specific range of applications.

Due to some project constraints such as time, capital available, access to building methods and materials, among other, it was developed two different models. One totally conceived from scratch, and design taking in consideration the requirements established for the project. These second design was intended to be build, creating a fully working prototype. This last was made from already produced bicycle components and was thought so that it would be similar to the conceived project and to maintain its most important features.

Both models were structurally validated using the finite element method with a static and frequency of vibration analysis. For each of the models was also chosen the best component configuration, this was made comparing each of the alternatives that each component presents and the advantages that they would provide.

A cost analysis was also made for both designs, which showed the different cost rates of the two designs.

CHAPTER 01
INTRODUCTION

The demand and execution of electrical vehicles is extending more and more as the days go by. New technological improvement allied with growing concerns with the environment and physical health had led to huge developments around this concept. Electrical vehicles are playing a major role in several industries, especially in the transportation field. The application of electric motors in bicycles and cars opens up new possibilities and a huge number of advantages. Electric motor vehicles are a concept to take into the world in the present and even more in the future, as they can be opened to new possibilities or even replace the possibilities given nowadays by the common internal combustion engines. In the current days, fully electrical cars can already directly compete with an internal combustion car or even control and make them look outdated in several aspects.

The application of electrical motors in bicycles has many benefits linked to it. It can provide assistance to the rider through tough mountains, to help fast achieve higher speeds or just to let the rider rest along the way, allowing him to do longer and unconditional ways with less effort. This concept can tell to be also very useful to people with movement difficulties, as it can transform and improve a common bicycle or similar vehicle to meet people’s needs, helping them in transportation and increasing its mobility.

A folding electrically help power cycles has many advantages, it doesn’t pollute the environment, it’s good for the health, allowing to exercise and to reduce the effort with the amount of power released by the motor. In a town environment it represents great mobility, it can be folded up and carry it into public transportation to reach near the destiny. Or otherwise, to ride it to the destiny, with the electrical motor help through the route. As a bicycle, it is very useful in traffic jams, as it allows to pass by stopped traffic and reach the destiny possibly even faster than public transportation like car and other transportation vehicles.

It gives a very small environment-friendly footprint, specially comparing with cars, onethat they are less or practically non-pollutant. Another character that increases this difference are the considerable difference in rates. Cars generally present occupation rates around 1 and 2
persons, representing 20 to 40 percent of its total capacity while bicycles use all its size rate, increasing order and reducing the footprint. One major problem is with the use of bicycles in big cities are the robbery’s, leaving the bike in the outside it’s always a risk, even the best locker can be overcome. With a folding bicycle, this problem doesn’t exist anymore as it can just be folded and taken inside withtherider, secure its safety. Comparing with a moped or motorcycle, it’s cheaper to buy in most of the cases and cheaper to maintain. You don’t need any kind of documentation or requirements to apply and they have very similar mobility characteristics through traffic and in a capital environment.

Objectives
This theory has the objective to consider the best alternative to be used as a daily mean of transportation to reduce to work. We should come up with a solution able to solve the problems inherent to the common urban means of transportation, as public transports, private cars or common bicycles and thus create a better alternative for this specific purpose. For such, we will be considering and study the best option from the several theory for an electrically assisted bicycle. This theory also has the end of building a fully working prototype within the possibilities that are given, this is, taking into consideration the time, capital available, access to building methods and materials among other constraints.

This bicycle, or electrically help power cycle, is meant and drawn for a very specific use and application: it is to draw to be used as a daily mean of transportation to cover the distance between house to work and vice versa. It should be transform to urban transportation, creating a different to other normal and less attractive means of transportation in a town environment. It should be the perfect choice to be applied in the "last mile" concept. This is a concept that refers to the last part of your daily work route. Whether it is straight from house to work or from the public transport or a private car. The bicycle has the objective of making your way to work simple, easy and remove the problems basic in the use of a common bicycle. Nowadays we also have the concern with the environment and the pollution, by using an electrical vehicle, you would have a vehicle with practically no pollution basic to it, making the way to work cleaned and greened and thus decrease the ecological footprint both of the rider as of the city itself.

Let’s predict the following pain where you live corresponding near to your workplace (about 5 km or more). This would leave you with a small distance to cover to go to work but still large distance to cover by base. Therefore the usual option would be a public transport, a common bicycle or a private car, but all these options can represent problems. Using the public transportation, more likely a bus in this case, you would always have flexible that you can’t and won’t control or control and that could lead to make you come late to the destiny. Variables such as the schedule of the bus, possible but still common late or even just the traffic, which is quite normal in big cities. With public transportation you also would have more cost, just to go to work. The common bicycle would be a good option as it has more flexibility and can easily overcome traffic or other urban barrier. Even so, using a common bicycle with hot weather or in mountainous paths can be tiring, weaken the rider and making him moisture and uncomfortable, even before arriving to the workplace. This likely would have an negative effect on the presentation and happiness throughout the work day. Another problem basic to the use of bicycles in city environments is the safety, daily loads of bicycles are stolen and never recover. Taking your private car would also be a good choice but this also raises real problems. Problems such as traffic or finding a spot to park. Another common plan is the one where the person works in a big city but lives in the outside, representing 20 to 40 percent of its total capacity while persons, representing 20 to 40 percent of its total capacity while bicycles use all its size rate, increasing order and reducing the footprint. One major problem is with the use of bicycles in big cities are the robbery’s, leaving the bike in the outside it’s always a risk, even the best locker can be overcome. With a folding bicycle, this problem doesn’t exist anymore as it can just be folded and taken inside with his rider, secure its safety. Comparing with a moped or motorcycle, it’s cheaper to buy in most of the cases and cheaper to maintain. You don’t need any kind of documentation or requirements to apply and they have very similar mobility characteristics through traffic and in a capital environment.

Methodology
Frame project
The frame is the most crucial component of a bicycle since it joins and holds together all the other parts. It is not only the component that links all the pieces since it has a big impact on the bicycle's performance, safety, and practically all other aspects. The diamond frame, which consists of two triangles as shown in the image but comes in a variety of sizes and shapes, is the most common choice.
A bicycle frame's design and conception must take into account a number of factors, namely its weight, strength, and stiffness. Additionally, and specifically in this project, the compactibility is crucial because a foldable bike must be as small and simple to store when folded. These are the primary characteristics that ought to be given more weight because they have a significant impact on the finished item and translate into the essential elements of a foldable bicycle.

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Despite having a lower density than steel, aluminium is more expensive in terms of both the raw material and the tools required to work with it. Even though titanium has an excellent corrosion resistance and high strength to weight ratio, it is still more expensive and difficult to work with than both steel and aluminium. Although carbon fibre has the advantage of being able to adapt to almost any shape, it requires constant upkeep.

**Decision Making**

We choose to employ a decision procedure in order to be able to make decisions in a less subjective manner. A quantitative method that is frequently used in engineering is the Pugh method, also known as the decision-matrix [7] method. Stuart Pugh, a British professor who worked in the departments of product design and development, engineering, and management at the University of Strathclyde in Scotland, created the method. A series of pairwise comparisons of the design candidates are the foundation of the Pugh technique. It enables the comparison of the various options using a wide range of criteria and, furthermore, manages to assign various weights to the various criteria, permitting greater or lesser priority to a particular criterion. This enables us to examine the significance of each criterion separately while taking into account our intended objective and purpose.

Prior to using the procedure, it is required to rank each of the criteria (from 1 to 5, for example), taking into consideration its significance to the decision-making process. A very important criterion that significantly influences the decision would receive a five, whereas an criterion of marginal importance would receive a one, and so on. This is known as the criteria weight, or, more specifically, how significant and impactful this particular factor will be on the decision-making process. It's time to rate how well or poorly each choice satisfies the criteria after each criterion has been chosen and ranked according to its value. This implies that an option should receive a high grade if it is an excellent alternative just based on this particular criterion. On the other side, a choice should receive a low grade if it doesn't meet the relevant criteria. This value so shows how each choice is categorised in light of a specific criterion. After the matrix has been completely filled out and graded proportionally, the outcome can be determined. The calculation is done by dividing the weight of the criteria by the grade that the choice in question got. The multiplication results from each of the criteria must be added up in order to get the outcome. We may quickly reach a choice by comparing the sums of each alternative, a judgement that is the consequence of comparing all the options and taking into account all the criteria.

**Global Positioning System GPS**

Since e-bikes have a power source, they present special opportunities for monitoring and understanding usage as well as their interaction with the urban environment, which may be advantageous to both e-cyclists and traditional cyclists. Understanding and communicating the potential advantages of e-bikes for sustainable transportation and beyond requires a thorough understanding of how they are used in certain geographical and cultural situations.

In this paper, the term "e-bike" refers to bicycles with a small motor and battery whereriders always have to pedal but can engage electric assistance (often with a choice of low, medium, or high settings) if they so choose. When the peddling stops or a speed of 15 m/h (25 km/h) is reached, the assistance stops. These electric bicycles, often known as pedelecs, are used in several European nations. There are other e-bike models available, such as those that allow assistance to be utilised without pedalling; these are particularly common in several Asian nations (see, for example, [1]), but they are outside the scope of this study. On e-bikes, a variety of motor and battery configurations are possible [2, p. 5], and the models used in this study represent two of the most widely-liked types: (i) a front-hub motor with a rack-mounted battery; and (ii) a crank-driven motor with a central battery.

In European nations with established cycling traditions, e-bikes are quickly gaining popularity among both experienced and novice cyclists [3]. For instance, in the Netherlands, the value of e-bike sales is on par with or higher than that of traditional bicycle sales; in Germany, one in ten bicycles sold is an e-bike; and it is believed that there are more than a million e-bikes in use throughout Europe.
[3]. They are still relatively unknown in England, nevertheless. A better understanding of how people in the UK engage with e-bikes could help to identify issues for policy, design and research that could lead to a higher uptake of e-bikes. The 2011–2014 ‘Smart e-bikes’ research project[4] worked on this and the EMARTS Bike Monitoring System (SEMS) has been developed as part of this work. The monitoring system is implemented on a fleet of 35 e-bikes in Brighton (UK).

**ELECTRICAL BICYCLES**

**CHAPTER 2 STATE OF ART**

Since they have been around for more than 200 years, bicycles have been a significant and widely used mode of transportation. Who created the idea for debate and cannot be known for sure. It is undeniable that they have changed significantly since their invention and continue to play a crucial part in contemporary life. More than 1 billion bikes—twice as many as automobiles—had already been built globally by 2003 [8]. They offer not only a practical mode of transportation but also a highly well-liked type of entertainment. They have been modified for numerous uses, including those in general fitness, military and law enforcement, couriers, bicycles, racing, and many more.

An electric bicycle is a bicycle with an inbuilt electric motor that helps the rider push the bicycle. Pedelecs and E-bikes are the two primary categories of electrically assisted powercycles; the difference between them is how the motor is activated. Pedelecs use a PAS, which means that as long as the driver keeps pedalling, the motor automatically aids him, and the motor shuts off if the driver stops. The sensors inside the motor, which typically gauge the pedalling rate, bike speed, or torque applied by the driver, automatically alter how much assistance is provided. These three types of sensors are not included in all designs, but more recent designs have them operating together, which leads to more controlled driving experience and an improvement in certain key features of an EAPC, like as range and comfort. E-bikes, often known as “power-on-demand” or “twist-and-go” bikes, use a throttle to trigger the rider to pull to move the vehicle forward. Additionally, some designs offer both operating modes.

Ogden Bolton Jr. of the United States published the first e-bike patent on December 31, 1895 [9]. It has a straightforward construction and is a rear-mounted direct current (DC) brushed motor. The motor could draw up to 100A from a fixed 10V battery and had no gears. This design, as shown in the figure, is quite similar to the models we have today.

The first brushed planetary geared hub motor with total RPM reduction of 5.6:1 debuted barely one year later with the aim of boosting the power and efficiency of the hub motor [10]. Surprisingly, the first electric bicycle with a mid-drive motor emerged just one more year later. Hosea W. Libbey re-filed the patent in the United States, but it was not successful in reaping the benefits of the mid-drive motor because it only spun at the same speed as the bike wheel [11]. Even though the first bicycles with integrated electric motors were modelled after electric motors that were patented in the 1890s, it wasn’t until the late 1990s that EAPCs really began to catch on. The development of better, more dependable, and more consistent electrical bicycles was made possible by new technologies. The idea of an electrically assisted motorised cycle began to expand significantly, and these began to be accepted as legitimate modes of transportation, beginning to compete with regular bicycles, motorcycles, and even automobiles. However, in some countries, the most recent ten years or even just recently, have seen the highest growth. As a result, the regulation related to this new class of vehicles is somewhat premature and is continually changing and developing. In an effort to harmonise the laws and safety surrounding this notion across all of Europe, the EU developed regulations and standards, which are now practically complete. When using EAPCs in environments where different parts are present, such as vehicles, pedestrians, other bicycles, and various other types of obstacles, the safety concept is one of the main concerns of the EU.

In addition to playing a significant influence in the market’s expansion, new technological advancements coupled with “sexier” designs have increased interest in demand and have foreseen electrically assisted power cycles. Components like the torque sensors, batteries, power sensors, and the motor itself were some of the most significant and recent innovations that played a significant role in the EAPC sector. The development and enhancement of these components allowed the sector to advance even further and gain prominence that it had not previously had. These innovations were extremely significant to the sector since they improved the idea and gave riders more fun and control while riding.

The electric bicycles improved in terms of dependability, cost, and energy efficiency. They also had longer ranges, which allowed for new uses. As more people become aware of the numerous benefits that these types of vehicles have in a city setting when compared to a car, a regular bicycle, a moped, or a motorbike, the demand for electric bicycles is currently expanding at a level that has never been witnessed before. In businesses like post offices and various urban transportation and courier services, electric bicycles are also beginning to be used in industrial capacity. Electric bicycles have a number of advantages over mopeds and low-powered motorbikes, and new, improved, and imaginative designs are making them the industry leader in several years. There are already new designs with amazing capabilities that let you connect the bike with your smartphone so you can control the electrical functions of the bike or charge your phone. There are also emerging new types of electric bicycles, such as hybrid and electric bicycles, in which the rider only pedals to charge the motor because the crankset isn’t connected to the wheel, or retrofit kits, which are also becoming increasingly popular as they develop and show better efficiency rates, resulting in significantly larger bicycles.

The expenditures associated with this kind of vehicle are currently its biggest drawback. Due to two primary components, the motor...
and the battery, purchasing an electrically assisted bicycle or converting a conventional bicycle to one can prove to be very expensive. Although the market is displaying an increasing number of different hypotheses, each with a different cost and power output, the concept has always required significant investment, particularly when compared to conventional bicycles. This is a problem that will only get better with time and in a market where the top brands in the sector are competing with one another. Fortunately, and as will be detailed further, the business for electrically powered bicycles is rapidly evolving with expanding designs and advances. As a result, it is anticipated that prices will decrease and become more attractive for this sort of car as the key components that drive up the price become more accessible and ubiquitous.

**LEGISLATION**

Because electrically assisted power cycles are a relatively new idea and are constantly being improved and evolving, the legislation governing them is still a little premature and is constantly being adjusted to the frequent changes and to the new risks associated with them. However, there are laws that set this mode of transportation apart from the others. Legislation for EAPC is difficult to establish since there are so many various types of bicycles, each of which poses a unique set of risks to both riders and the environment. These bicycles also have varying power outputs, work modes, and uses. The laws governing these kinds of vehicles will be briefly described in this section, with a focus on Europe, Portugal, and some of the major producers and consumers of this technology, including the United Kingdom, the Netherlands, China, and the United States of America.

**Europe**

The European Directive 2002/24/EC distinguishes between bicycles that must be regarded differently than other bicycles due to the assistance an electric motor provides, such as motorized or motorbikes, and those that can continue to be treated legally as conventional bicycles. "Cycles with pedal assistance that are equipped with an auxiliary electric motor having a maximum continuous power output of 0.25 kW, of which the output is progressively reduced and finally cutoff as the vehicle reaches a speed of 25 km/h, or sooner if the cyclist stops pedaling," is how the directive defines the requirements for electrical bicycles.[12] If a bicycle fits these criteria, the laws that apply are the same as those that apply to a regular bicycle without any sort of assisted motor.

Directive 2002/24/EC stipulates that bicycles with stronger engines or different operating systems are regarded as mopeds or motorbikes. The restrictions that the driver must follow vary depending on these groups. It has an age restriction that varies by country, and the driver must have a driving licence and wear a helmet when driving. The car must be insured and have an alinace plate. In this situation, the vehicle must also go through a type-approval by an authorized body that checks to see if it complies with the requirements for mopeds or motorbikes. However, in the majority of the member states, there is no legal requirement to follow this standard. However, the General Product Safety Directive, 2001/95/EC, is a requirement that must be followed by all manufacturers in the EU[14]. In essence, this law mandates that producers make certain that the goods they release to the market are trustworthy and safe. In the majority of the member states, manufacturers are free to certify their goods by putting them through internal testing or hiring outside testing agencies. EAPC is divided into two separate groups under EN15194. Both classifications are included in the previously mentioned category of motor vehicles, and the output of the motor is 0.25 kW, whose output gradually decreases and then is shut off as the vehicle reaches a speed of 25 km/h or sooner. This distinction results from the relative differences in the motor’s actuation methods:

- **Pedicel:** The motorised assistance only kicks in with this sort of bicycle while the rider is pedalling. The motor shuts off when the driver stops pedalling. These bicycles typically have a pedal motor system attached to the crank and linked to the gear box.
- **E-Bike:** In contrast, these bicycles have a motor that can move the vehicle forward on its own, i.e., without the rider having to pedal. Hub-motors are frequently installed in the front hub, the rear hub, or both. Due to their resemblance to mopeds or low-powered motorbikes, they are also known as "twist-and-go" bicycles, and in some countries, the laws governing them are substantially different.

As previously stated, EN15194 is concerned with the bicycle's electrical components. The bicycle’s performance and safety, as well as the tests it must pass to be deemed safe for use, are outlined in EN14764[15]. This standard demands high-quality items and stringent safety criteria in order to ensure the integrity and strength of both individual components and the bicycle as a whole. The standard was created to provide the highest level of safety for bicycles made in the EU.

**United States**

The term "Low speed electrical bicycle" is used to describe the category of electrically powered bicycles that is most similar to those in Europe. All two- or three-wheeled vehicles with fully functional pedals that have an electric motor that produces less than 750 W and a top speed of less than 20 mph (32 km/h) fall into this category. A bicycle that nevertheless complies with these requirements is covered by the CPSC's consumer product standards for bicycles and is exempt from being categorised as a motor vehicle. States have different laws governing the use of electrical bicycles on sidewalks, public roadways, and other surfaces. Over these power and speed limits, all commercially produced electrical bicycles are subject to USDOT and NHTSA regulations as motor vehicles and are subject to additional safety requirements.

**MARKET**

With an estimated 85% of all electric bicycles sold worldwide being sold in China, China has long dominated the global market for these vehicles. This is owing to a number of factors, including the government’s official designation of development in this area as a technical objective in 1991 and the recent legalisation of petrol-powered mopeds and scooters in many cities. The Chinese market started to expand exponentially in the year 2000, going from 300,000 sales in 2000 to an astounding 30 million sales in 2012[18].
Figure 2.3: Evolution of the Chinese market

Despite the delay, the market in Europe and North America only recently began to take off and is now a multi-million dollar industry, particularly in the northern European nations like the Netherlands, the United Kingdom, Germany, and Belgium where cycling has a long history. According to estimates, 83.2% of all e-bikes imported into the EU in 2014 came from China [19]. The high cost of petrol in the majority of European nations was another significant element that contributed to the rapid growth of the e-bike business. This, combined with an increasing awareness of environmental issues, led individuals to start looking for less expensive alternatives to vehicles and motorcycles that pollute less. Costs, which are quite pricey when compared to a standard bicycle, were one of the key issues that limited market expansion.

Figure 2.3.1: Evolution of the European market [20] (1000 units per year)
According to Navigant Research, a base scenario predicts that annual sales of e-bikes will increase from little under 32 million in 2014 to more than 40 million in 2023. The market growth has been fueled by innovative trends and will remain so. E-cargo bicycles are now being employed as a form of transportation by a number of businesses, including the post office, the police, security firms and others. The e-bike industry is becoming even more appealing thanks to hybrid designs and retrofit kits, and as time goes on, more and more designs with various characteristics proliferate, making EPACs more practical and with a wide range of applications, not just in private transportation.

**BICYCLE COMPONENTS NOMENCLATURE**

1. spoke
2. tire
3. rim
4. seatstays
5. rearbrake
6. seatpost clamp
7. seat
8. seatpost
9. brakecable
10. headset
11. stem
12. handlebar
13. brakelevers
14. headtube
15. forkblade
16. valvestem
17. fromthub
18. front dropout
19. rearhub
20. pedal
21. crankarm
22. crankset
23. chainring
24. chainstays
25. chain
26. reardropout
27. rearhub
28. seattube
29. toptube
ELECTRICALLY ASSISTED BICYCLE COMPONENTS

Motor

There are various ways to power a bicycle; the ones taken into consideration in this work and more frequently employed include mid-drive motors, hub motors, and friction drive motors. In order to be able to select the motor that will best meet the demands placed on the bicycle, we will be looking at both the benefits and drawbacks of the different motor types in this part.

The city of Lisbon, which is well-known for its steep and lengthy hills and is sometimes referred to as “Cidade das setecolinas” (“City of the Seven Hills”), served as inspiration for the design of the bicycle. The Portuguese capital's roadways have seen better days, and some of them currently have very shoddy pavement. In the Portuguese city, potholes and broken rails are a common sight. While they don't pose a severe threat to automobiles, they can be extremely dangerous for motorbikes and bicycles and result in serious accidents.

The simplicity of friction drive motors—both the motor itself and the mounting procedure needed to build them—is their primary distinguishing feature. Despite its ease of use and small size, this type of motor is the least popular of the three under consideration because it has a number of shortcomings compared to the others. A spinning roller that is placed against the bicycle's tyre and causes it to spin is how the motor transfers power to the bicycle. Despite having benefits like their small size, light weight, and high power-to-weight ratio, they are primarily noted for their poor efficiency at transmitting power to the bicycle. This friction coefficient can soon diminish and won't be enough to push the bicycle, especially in wet conditions. Power transfer is made possible by friction between the motor drive and the bicycle's tyre. Typically mounted in the seat post, they are very simple to mount and demount on a bicycle without the use of any tools.

Mid-drive motors, Located inside the crank shaft, these devices are also known as crank motors. The fact that mid-drive motors drive the crank rather than the wheels allows them to take use of the 16 gears on a bicycle, which multiplies their power, is one of the main factors contributing to their high performance and torque rates.

This sort of motor's placement within the bike and impact on the mass centre are additional benefits. It is installed in the middle of the bike, which lowers the mass centre and...
keeps it in the middle of both wheels, improving the rider's control, stability, and manoeuvrability. These offer noticeably higher torques and speeds compared to hub motors with the same motor power, despite being more expensive. The crank and chain of a bicycle are the only parts that can exert a certain amount of force after the power is transferred to them. Additionally, this suggests increased deterioration of the bicycle transmission's parts. One strategy to alleviate this wear and tear is to briefly reduce the power when shifting, much like you would on a regular bicycle. Mid-drive motors are very advantageous when used with a bicycle that has suspension because the suspension would lessen the vibrations and shocks felt by the motor and leave the wheels lighter, allowing them to rebound quickly and efficiently, creating a more fluid and comfortable ride.

There are two types of mid-drive motors: those that are designed to turn a regular bicycle into an electrically assisted bicycle. These can be used with the majority of modern bicycles and are mounted in the bottom bracket. The second group includes motors that need a particular frame with the correct mountings and space to fit the particular model of the motor in the frame. In this instance, the bottom bracket acts as the motor itself, opening up the possibility of using a torque sensor to gauge the torque a rider applies.

![Example of a hub motor.](image)

Using a different parameter of the rider's actions or modifications to the bicycle, the engine may be controlled considerably better to operate in a way that will support the rider. A product becomes more sensitive and user-friendly as a result.

Hub motors typically have lower power outputs (250 to 350 W), especially those used in the front wheel since excessive power would cause the front wheel to spin and the bike to lose control. However, there are much more potent motors on the market that can produce up to 1000 W of power. This type of motor has a long history, dating back to the original electric bicycles, and is currently the most often used alternative since it has been "tried and true" and is therefore the most economical option. They are made in great quantities in China, making them quite accessible and inexpensive.

These motors feature fewer moving parts, which reduces wear on the motor, the chain, and any other transmission-related equipment. Although they are mounted in sealed cases and don't need any maintenance, the sealed case can be dangerous and cause overheating problems because there is no easy way for the heat to escape. With these motors, it is simple to turn almost any regular bicycle into...
an electric bike, especially when using a front hub motor. Due to the fact that they do not obstruct the pedals or the gearbox, the potential loss of front wheel traction would be the major drawback. A rear wheel hub motor can make mounting a bicycle's derailleur a little more difficult, but it also reduces the possibility of the wheel spinning and losing traction. Regarding weight distribution, they might throw off a bike's balance in the front or the back, making it more difficult to handle and control. Another disadvantage is that they will absorb all the stress and vibration produced by the ground track after they are positioned in the centre of the wheel. Over time, this could result in issues or malfunctions. Hub motors make changing a flat tire much more difficult, primarily due to the wiring that is attached to the wheels.

**Geared hub motors.** Unlike gearless hubs, they don't produce drag when the power is off. For every rotation of the case, the motor inside will actually turn many times faster, making them better suited for hillshangeless motors. Typically, they have their cases connected to the stator through a planetary gear reduction system. This enables the motor to operate at faster, more effective speeds, resulting in smaller, lighter motors that can create more output, but it also causes more wear, noise, and friction.

![Geared hub motor](image1.png) ![Gearless hub motor](image2.png)

**Gearless or direct-drive** Since hub motors lack a gear system, as their name implies, one rotation of the motor corresponds to one rotation of the wheel. Compared to geared motors, are recognised for being exceedingly simple and having essentially no moving components. Sincethey need to have a large diameter in order to produce enough torque, direct-drive motors are typically bigger and heavier. They generated drag when unpowered because they only use electromagnets and may not have a freewheel mechanism. Some suggest using regenerative braking to recharge the batteries.

**Frame**

The bicycle frame, which connects all the other bicycle elements and is where these are installed, is the primary component of a bicycle, as was previously stated in Chapter 1. It greatly affects the bicycle's functionality, safety, and almost every other element. Once the frame is what makes the bicycle foldable, it has a significant impact on the bicycle as a whole, especially incases where the bicycle is a foldable one. The weight, rigidity, strength, and, in this case, the capacity to fold into small space are the key characteristics of a bicycle frame.

The most popular materials used to make bicycle frames are carbon steel, chromoly steel, aluminium, titanium, and carbon fibre. Steel is the most frequently found in bicycles; it has been in use for a very long time and is also the least expensive of those mentioned above. It is made of a durable substance. In comparison to other materials, it is known to be simpler to work with, and the tools required to do so (welding machines, welding gases, etc.) are also less expensive. Its great density, which makes it the heaviest substance taken into consideration, is one of its main drawbacks. Although aluminium is less dense and less strong than steel alloys, it has a higher strength-to-weight ratio, allowing for the construction of lighter frames. Although it is more expensive than steel alloys, it is becoming less expensive and is used on a lot of modern bicycles. It is among the greatest materials for this kind of application since it is lightweight, sturdy, long-lasting, and rigid. While titanium is stronger than steel, it is also lighter. Ti frames stand out for their strength, damping ability, and lightweight. Since the material naturally resists corrosion, titanium frames are typically not painted, so they don't require any additional protection. He can bend while preserving his shape thanks to his damping ability, which makes the ride more comfortable and shock-absorbing. The price is the main drawback. In addition to being a priceworthy material, working with it calls for special equipment and abilities.

The most often used material for performance road bikes nowadays is carbon fibre. It is extraordinarily light—some carbon fibre bicycle frames weigh less than 700 grams—and sturdy enough to be pushed to the limit in some of the world's most difficult competitions. The major drawback is that, in contrast to metals, it is exceedingly fragile and readily breaks. This is so that loads in one direction can be supported by the carbon fibre frames, which cannot be outweighed by loads in other directions.
The ability to fold the bicycle is the primary feature of folding bicycles. The bicycle can be folded and compressed in an infinite number of ways. The ones where the bicycle folds horizontally, vertically, or both ways are the most prevalent. Another typical application of telescopic tubes that enables the frame to retract. The most frequent fold is the horizontal one, which typically occurs at the centre of the frame on a single hinge, leaving the wheels very close together and practically concentrically aligned. The ability to move the folded bicycle as a sort of trolley is made possible by having the wheels lined up, making it easier to transport. The wheels would be close but in a different alignment if the frame were to just fold in half, which would prevent this from working properly. To enable the wheels to be completely aligned, a fold must be made in a dimension parallel to the wheel alignment.

Wheels
A bicycle's wheel is a crucial component, so care must be used while choosing its size. One of the major aims of a folding bicycle is to minimise the space that it takes up and the weight. At first glance, using small wheels seems like the sensible decision, but they have various drawbacks when compared to wheels with larger diameters. Small wheels reduce a bicycle's mobility, which is one of the main benefits of riding one as a mode of transportation, particularly in an urban setting, where that is what it is designed for. Simple obstacles like pavements or tiny steps can be difficult to navigate with small wheels. Any crack or stone in the pavement, no matter how small, can throw the rider off balance and put them and anyone else nearby in danger.

Although using wheels with large diameters makes the ride safer, more stable, and easier to manoeuvre around obstacles, as was already mentioned, one of the main objectives of this work is to reduce the amount of space that the bicycle takes up. Therefore, we must select a wheel size that is as small as possible, maintaining the bicycle's compactness while still being large enough to allow easy manoeuvrability and a comfortable ride.

Two measurements are necessary to define a bicycle wheel: one to specify the wheel's diameter and the other to specify its width. The dimension that stands out the most and has the greatest impact on a bicycle is its diameter. The available sizes range from 8, 10, 12, 16, 20, 24, 26, 28, 29, and 32 inches, with some intermediate sizes, typically from vintage or extremely specialised bicycle designs. The lower sizes mostly only find use in children's bicycles and wheelchairs and have limited applications. The 16" and 20" sizes are typically utilised in BMX, kids'bikes, and light-weight riders. The majority of mountain and road bicycles utilise tyres in the sizes 24" to 29", which have the most market uses. Unicycles and various novelty bicycles may have sizes as uncommon as 32" or even 36".

Figure 2.5.7: Different wheelsizes
Any electric bicycle's heart is its battery. Without the entire amount of energy stored in the battery, the motor is worthless. It is frequently the most expensive and one of the hardest to get components. Any electrical bicycle's choice of this essential component must take into account the function for which the bicycle is intended as well as the desired range. Of course, it must also be compatible with the bicycle's other parts, including the controller, the motor, and all of the electrical parts. Lithium, nickel, and lead-acid batteries are the three most popular and often used types in electric bicycles; each has a number of benefits and drawbacks.

Li-ion batteries, like the others mentioned, are rechargeable; during discharge, lithium ions migrate from the negative electrode to the positive electrode; during charging, they move back. Many laptop batteries, cell phones, electric cars like the Tesla Model S, and other applications use them. They come in a variety of sizes and shapes and are all often referred to as “li-ion batteries,” a term used to refer to an entire class of batteries.

Lithium batteries come in a variety of material and chemistry combinations, and as time passes, more and more of them with unique and arguably better properties appear on the market. Though they may only account for a small portion of the market, the following alternatives are some of the most popular and well-known, particularly in the e-bike sector:

- **Lithium Iron Phosphate (LiFePO₄)** – One of the first extensively used materials in the e-bike industry, and one of the most common today. With a lifespan of 2000 charge cycles or more, this particular type of li-ion battery has the longest longevity of the others. These li-ion batteries are the safest when compared to other li-ion batteries because of their naturally safe and nearly fireproof chemistry. Additionally, they are among the biggest and heaviest members of the lion class. One disadvantage is that most of them have rather low discharge rates, making them unsuitable for electrical bicycles with significant power output. Despite this, they work perfectly for everyday bikes. Additionally, these cells require a protection system, commonly referred to as a Battery Management System (BMS). By doing this, the cells are prevented from going out of balance, from being overcharged, or from being discharged throughout the subsequent charge and discharge cycles. The majority of lithium-ion batteries require this protective circuit in order to avoid becoming harmful and having their life expectancy suddenly cut short.

- **Lithium Manganese Oxide (LiMn₂O₄)** - This form of lithium-ion battery is a reasonable compromise between the other types in terms of size, weight, safety, and price. The main drawback is that it has a relatively short lifespan compared to other...
lithium-ion batteries, typically only permitting 600–800 charge cycles. Despite being able to handle more even charging and discharging, most battery packs include a BMS.

- Lithium Nickel Manganese Cobalt Oxide (LiNiMnCoO2) is a relatively novel material for these kinds of applications. It sprang to fame around 2013–2014 but is now quickly dominating the electric bicycle sector. They have a secure chemistry that enables them to offer great power in a lighter and more compact form factor than the first two types. Due to their extremely low rate of self-heating, these batteries are also frequently chosen for use in electric vehicles.

- Lithium Polymer Batteries (LiP o) - Of all the lithium batteries mentioned, these are the smallest, least expensive, lightest, and most potent. However, they have a number of drawbacks, such as a limited lifespan (a few hundred charges) and a propensity to catch fire and explode into enormous fireballs. This is because of their unstable chemistry; if they are not handled carefully and correctly, they will ignite and catch fire if they are overcharged or overdischarged, pierced, or dropped. In essence, they must be handled carefully or else they might become highly dangerous, and in this particular use, where they are intended to be employed close to the rider or even between its legs, they are not a secure option. In the remote control sector, as well as in vehicles, planes, and other things, these are frequently utilised.

Another variety of rechargeable batteries on the market are nickel batteries. These were used before lithium batteries and are primarily found in portable equipment like power tools, flashlights, electric vehicles, and remote-control toys, among other things. They have gained appeal as lead acid battery replacements since they offer significantly better features. Despite this, lithium batteries have largely taken their position in most uses and applications. They need to be assembled and charged carefully because they have a short lifespan.

Another choice would be lead acid batteries, which date back to circa 1860 and are the oldest of the three battery types previously mentioned. Despite being an outdated technology, they continue to see advancements and are still widely used across the globe. Because most fuel cars use the same kind of battery, they are widely available and simple to access. They are significantly less expensive than Li-ion or nickel batteries, which is mostly owing to their weight and capacity. They weigh three times as much as lithium batteries and twice as much as nickel batteries due to their low energy-to-volume and energy-to-weight ratios. A crucial component that must be ensured, particularly for this kind of use, is that the battery is what is known as a Sealed Lead Acid (SLA). If not, the acid may start to leak from the battery and create a hazardous situation.

\[ \text{Figure 2.5.11: Examples of different lead acid batteries} \]

Throttle/Pas

We will discuss the options for regulating the level of motor assistance in this section. It is a very significant feature, and with the appropriate control, you can either use the motor to its full potential or only lightly, greatly extending the range. There are two major techniques to manage how much aid the motor provides to the rider, albeit there are minor variances between these two:

- **Throttle** - The idea is essentially the same as with a regular motorcycle. These make it possible to instantaneously and directly control the motor's output of power. There are a few different kinds, including thumb throttles (where the throttle is engaged
by pushing the lever forward with your thumb), full twist throttles (found on most motorcycles), and half twist throttles (where the throttle is engaged by twisting the throttle grip, in this instance only the lower half of the grip). These are the most typical bike throttles in use.
Pedal Assist System (PAS) - The term "pedelecs" (pedal electric cycle) is also used to describe a mode in which the motor only operates when the rider is pedalling; otherwise, it will shut off. The degree of help is controlled by an electrical circuit that considers data from three different sorts of sensors: speed, cadence, and torque (not all models have all three types of sensors combined). The controller will cause the motor to spin more quickly the faster the pedal cadence, just as it will with a torque sensor or a speed sensor. You can pedal very lightly or extremely forcefully and still receive the same degree of assistance since the cadence sensor measures the number of times your pedals are turned each second. It is fixed to the bicycle frame, and the crank, which may have one or more magnets mounted, counts the crank's rotations. The torque sensor, which gauges how much torque the rider is applying to the pedals, is typically located on the pedal crank or next to the rear dropout. The speed sensor, which operates on the same principles as the cadence sensor but monitors the real speed of the bicycle, is typically put in the spokes of the bicycle.

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made an effort to employ materials and construction techniques that are generally accessible and ubiquitous. With this, we aimed to create an electrically assisted bicycle that could compete with the present market while also meeting all the demands and specifications we had presumptively identified for a bicycle made for this particular use. It is vitally important to remember that this design only represents a base case; more testing and refinement are required to produce a good and trustworthy final product.

When it becomes clear that we won't be able to construct a prototype in this manner, we must think about an alternative design that falls within our realm of possibilities. We'll make an effort to preserve the primary elements and top qualities of the earlier design in this one. To create a completely functional prototype, it should be as similar to the one we've created from scratch as feasible while still being within the realm of possibility. This prototype is meant to be reconstructed using existing bicycle components and modified to provide a testable and practical prototype.

After identifying the project's primary criteria, we will show both designs in this section, outlining their key characteristics, the judgement we had to make for each component, as well as the factors that influenced our choices. Additionally, we will assess the key distinctions between the two designs and the practical effects these modifications would have on how the bicycle is used.

**PROJECT REQUIREMENTS**

There are a number of aspects that go into projecting a vehicle, and those factors increase if the vehicle is made for a particular use or application, as is in this work. Therefore, it's crucial to establish some fundamental requirements, even though some are more crucial than others. We shall outline the principal specifications and goals that the vehicle must be able to demonstrate or accomplish in the course of its use:

- **Autonomy** - This element is crucial in all types of vehicles, but it is crucial in electric alone because it restricts the rider's options and limits the vehicle's range. Additionally, charging the battery takes time and requires a power outlet and a battery charger; in other words, if the battery completely discharges while travelling, it cannot be charged without certain conditions and equipment. We've thought about the idea that a bicycle has a defined use, two daily routes, and a constant path, such as home-work-home or home-public transportation-work, then returning home. According to a 2011 census analysis, covering the areas of England and Wales, those living and working in London had an average daily distance to cover of 11 km when travelling to and from their place of employment. With this in mind, we established a minimum autonomy of 25 km, figuring that it would be sufficient for daily operations or provide for the ability to travel further if necessary. This autonomy can be readily increased by utilising two sets of batteries, one serving as a backup for the other while using one battery, or by using a larger battery with a higher capacity, but larger capacities result in heavier batteries which are in conflict with the weight requirement.

- **Weight** - This is crucial; criteria on safety that is frequently used to describe and rank bicycles. The bicycle must, of course, be as light as possible, but we must be realistic and understand that we won't be able to design a truly light bicycle in comparison to those on the market now if we are constrained by the production procedures and materials that are currently available. However, the weight will be a constant worry throughout the project, and will have a significant impact on every decision we make.

- **Convenience of transportation** - The bicycle will be quite heavy when it is complete, maybe too heavy to be carried over long distances. Therefore, a solution should be found to make it transportable when folded while compensating for its weight. It is best to fold the bike in such a way that it can be transported folded, in a small package, with both wheels on the ground, and in a form that is both balanced and user-friendly.

- **Easy to fold** - A folding bicycle's folding system is an essential part. To maintain the bicycle rigid and stiff, it needs to be sturdy and safe, but it also needs to be practical and simple to lock and unlock. The bicycle must be able to be folded and unfolded quickly and conveniently, but it must also provide reassurance that once closed, it won't accidentally fall intentionally unclik, which could put the rider in danger.

- **Safe** - As with any vehicle, safety is a key and important necessity. Because bicycles are intended to be used in public settings, every project must be developed and conceived with the rider's safety and the safety of any bystanders in mind.

**CONCEIVED DESIGN**

*Component and Material Selection Motor*

A motor is an essential part of an electrical bicycle, thus care and consideration must be used while selecting one. The frame, tyre size, and gear selection of the bicycle must all be considered while selecting the best motor. The reason for which the bicycle is being used is just as crucial as, if not more so than, the motor choice. A bicycle made for weekend rides or riding in off-road terrain, for example, has a significantly different set of features and characteristics than one made for urban amode of transportation in a city context. There are three different motor types that can be used in our design, as described in section 3.

These include mid-drive, hub, and friction-drive motors. Each of the three has distinct benefits and drawbacks and is best suited for particular uses and circumstances. The friction-drive motor is the first of three optionstoberuled out sincethey have a number of drawbacks when compared to the other two. They are prone to failure than the other motor types even though they are simple—but both the motor and the process of converting an electric bicycle into an electrical one are simple. The power gearbox occurs due to frictionbetween backwheel and motor drive, as was previously discussed in the chapter. The performance and output of the motor are significantly influenced by the friction coefficient between these components. The motor drive may slip on the tyre, defeating the function of the motor, if the friction coefficient varies considerably, is easily diminished, or even disappears. Such situations that are problematic for bicycle use can happen frequently for a variety of reasons, including wet weather, tyre tracks, vibration from uneven ground, and even trying to move up a steep hill. These situations call for high torque rates, which can
easily overcome the friction required to move the bicycle forward. Hub motors and mid-drive motors are the only remaining motor types. Both are regarded as viable options and the best options for the given situation. Each one has its own benefits and drawbacks, and we will use the Pugh Method to help us weigh all the factors that will influence our decision. With this, it is anticipated that we will be able to make an intelligent and justifiable decision between the two options.

Prior to choosing a motor, it's crucial to establish the criteria that will be considered, as well as the relative weight and significance of each criterion in light of the intended use and potential uses of the bicycle. In this study, we took into account nine different factors, each of which was given a weighting of 1 to 5 (with 1 being the least important and 5 the most important) based on how significant a role it plays in selecting the optimal motor choice.

- **Weight** - When discussing a bicycle, weight is always a crucial consideration. The weight of the motor, which typically accounts for 25% or even more of the total weight of the bicycle, has a significant impact on the overall weight of an electrical bicycle. This aspect was thus identified as having the most significance among the others for the motor choice. Given that it will likely need to be carried in weight at some point along the path, this bicycle’s intended use may reveal its importance in overall performance. According to this classification, hub motors received a score of 5, whereas mid-drive motors received a score of 4. Hub motors typically tend to be lighter, despite the fact that both motor types generally show equal weight fluctuations. Nevertheless, a lot depends on the motor itself and which manufacturer made it. As a result, the motor type has less of an impact on weight variation than the motor itself.

- **Mass centre** – This criterion focuses on the impact that the motor’s mounting position has on the mass centre of the bicycle. As previously mentioned, the motor often makes up 25% of the total weight of the bicycle, thus it has a significant impact on how the mass is distributed over the frame. The location of the bicycle’s mass centre, or the combined mass of the rider and the bicycle, affects how the bicycle handles and responds to the rider. Thus, this is another crucial element in the decision regarding the motor. Hub mass distribution shifted closer to the front or rear, whereas mid-drive motors have the motor placed in the hub. This is not the greatest choice, especially when considering the mid-drive alternative, because our goal with regard to mass distribution is to have the mass centre as low and centred in the bicycle as possible. As was previously said, this type of motor is situated closer to or inside the crankset, which is thought to be the finest location to be once it lowers and centres the mass centre. Due to this, we have given the hub motors a score of 1 and the mid-drive options a score of 5.

- **Performance** - Mid drive motors are able to produce better outcomes and with higher torques when it comes to performance. This is primarily due to the fact that they can transmit more power because it is passed directly to the crankset and chain, enabling them to operate with the bicycle’s built-in gear system. Hub motors, in contrast, are situated in the centre of the wheel, requiring the motor to exert more energy to provide the same output. When contemplating a front hub motor alternative, a motor with high torque rates would cause the front wheel to spin and lose traction, hence hub motors are unable to achieve the same torque that mid-drive systems can. We have allocated 2 to the hub motors and 4 to the mid-drive alternative as a result of this.

- **Price** - Hub motors are more affordable than mid-drive motors in terms of price. Hub motors are a form of motor that is now widely accessible on the market and are simpler than other types of motors, which accounts for their various cost rates. According to the previous chapter, these motors originally arrived with the first electric bicycles around 1900, making them considerably more accessible now and less expensive than mid-drivemotors. Mid-drivemotors were given a score of 3 and hub motors a score of 5, respectively.

- **Wear and tear** - Although this criterion initially appears to have no bearing on the bicycle, it might later disclose to be troublesome and result in additional costs. A continuous lubrication and inspection on the components that suffer from significant wear and tear can avoid or forecast accidents. Of course, there are techniques to prevent or decrease wear and tear as much as feasible. Since all the parts of a hub motor are contained inside the hub and there aren't many moving parts, neither the motor nor the bicycle’s parts are subjected to much wear and tear. Because mid-drive motors have more moving parts and, as is common knowledge, transmitting power through the crankset is more complicated than transmitting power through the chain and chainrings, this criterion requires more maintenance and causes some bicycle parts to wear out more quickly. As a result, we assigned 2 to the mid-drive motor option and 4 to the hub motor.

We can infer that the optimal option for the motor would be a mid-drive system after conducting this comprehensive research and taking into account the choice method findings, which were 100 for hub motors and 117 for mid-drive motors. This is not to say that hub-motors are bad systems or that they are a poor choice for electrically propulsion of a bicycle; on the contrary, they are a good choice and a “tried and true” system. Even so, mid-drivemotors should be superior option to meet the needs for this particular spectrum of applications and when taking into account the criteria chosen in the decision approach.

Knowing that we would utilise a mid drive motor, the decision now centres on which of the many motors on the market we will employ. They can be broadly split into two groups: those that require a specific frame with fixation points and contours that match the motor, and those that can be put in the bottom bracket of the majority of bicycle types, turning virtually any regular bicycle into an electrically assisted bicycle. We chose this option because the first group includes the better and more inventive motors now on the market, and because building the frame would make it easy to create the proper fittings and mountings. The ‘Bosch ebike system,’ “Shimano Steps,” or “Yamaha ebike system” were among of the motor’s potential makers. These are well-known companies, and their products appear to be among the best available on the market. The three systems under consideration use three different types of motors: sensors—caden, speed, and torque—and all three have quite effective systems. These contribute to the creation of a simpler, more user-friendly interface between the rider and the bicycle, producing a very user-friendly product.
As for the battery, we want to create the battery pack once the frame is constructed entirely from scratch. As previously mentioned in the chapter, the battery pack is intended to be installed inside the frame, therefore doing so would enable us to customise its shape and adjust it to better fit the frame, making it invisible during assembly. The whole battery wiring and connections to the motor would be concealed and inaccessible from the outside by being housed inside the frame. All batteries share the characteristic that increased power and storage capacity result in increased weight and volume.

First, the choice relies between the three major types presented: Li-ion, Nickel, or Lead-acid batteries. Being the oldest battery type among the others, lead-acid batteries also have the fewest benefits and the most drawbacks. They are far heavier and larger than lithium or nickel batteries, and as was previously stated, weight and volume are crucial requirements for this project. Due to the fact that they typically only permit up to 500 charge cycles, they also have substantially lower life expectancies. Lead-acid batteries are less effective in transmitting power and lose energy during both charging and discharging than lithium batteries, which have efficiencies that are very near to 100%. Lead-acid batteries have another significant drawback in that their voltage consistently decreases during the discharge cycle. This has an impact on riding conditions because the bicycle loses power as the battery is being discharged, but it can also cause issues with other electrical components like the motor.

When choosing between nickel and lithium batteries, the main distinction is in how much energy can be stored in each type of battery. Because nickel has a lower energy density than lithium, nickel batteries are larger and heavier than lithium-ion batteries with equivalent power and energy storage capacities. Comparing lithium batteries to nickel batteries reveals various benefits. Lithium batteries have a longer expected lifespan, produce greater voltages, and require significantly less time to recharge (up to 70% less time, depending on the batteries). Nickel batteries must be completely depleted before charging in order to avoid the memory effect, which occurs when batteries are frequently recharged while still only partially discharged. Maximum amount of energy. However, lithium batteries also have drawbacks. For example, they are more expensive than nickel chemistry batteries and need an additional part called a protective circuit, also known as a BMS (battery management system), which was covered in the chapter before. In terms of their effects on the environment, lithium batteries are secure and free of dangerous substances, but the same cannot be said of the nickel chemistry, particularly the (NiCd) battery, which contains 6 to 18% of the deadly heavy metal cadmium. These necessitate special care during battery disposal, and in some nations, like the United States, a fee for the battery's proper disposal at the end of its service life is included in the price of the battery.

Following this analysis and taking into account the three battery types' benefits and drawbacks, it is clear that lithium batteries are better suited for the type of use that they are intended for. However, because there are numerous variations and material combinations for lithium batteries, we must select the battery pack's chemistry and format based on their suitability. We have decided on lithium manganese oxide (LiMn2O4) after carefully weighing the qualities and formats offered by each lithium battery chemistry. In the world of electric bicycles, this is the most typical lithium battery chemistry. It is a battery type that is extensively used and has favorable qualities in general, including size, weight, and price. Also among the safest of the lithium battery alternatives, this chemistry. We chose the 18650 battery type for the battery.

It is a battery design that is well known for the advantages it offers, including the affordability, the variety of applications, it may be used for, the possibility of purchasing from reputable manufacturers, and its longevity. This design was created by manufacturers to produce a dependable and multipurpose battery. Although the characteristics of 18650 batteries can vary depending on the model type or manufacturer specifications, their key characteristics can be generalised. They developed into a reliable and secure alternative, which inspired some reputable manufacturers, like Sony and Panasonic, to develop and produce the lithium-charged battery. Higher production rates and lower pricing were the result. The 18650 battery continues to be produced in greater quantities and at lower costs as researchers discover...
new applications for it, making it very well-liked by electronicgadgetbuyers. Liquidleakage from electrodes are prevented by the battery's cylindricalshape. The size of 18650, which is 18mm in diameter and 65mm in height, is how it acquireditsname.fabricatethelithium-ionbattery.

Figure3.2: 18650battery

Today, there are already a number of alternatives and businesses that produce and sellbatterypackssimilar to the one described and that we intend to build. However, by purchasing a battery pack that has already been made, we would not be able to customise it to fit inside the frame and be unnoticeable.

Wheels
As previously mentioned, wheels and wheel size play a significant role in the bicycle. They significantly affect how the bicycle rides, handles, and feels in terms of comfort and smoothness. We should choose a small wheel size if one of our key goals is to minimise the amount of space the bicycle takes up. Despite this, narrow wheels make it difficult or unsafeto manoeuvre a bicycle around obstacles like kerbs and potholes in the road. Therefore, we determined that 20” was the best size for a bicycle with these kinds of applications. The bicycle's modest size is sufficient to keep it compact, but it is still large enough to be safe and readily navigatethemostchallenges presentedbyacitysetting.

ModelDescription
Only the frame in this model was created in a CAD programme with the intention of being built, despite the fact that all of its components are depicted in a 3D model. This frame was planned and thought out in order to meet the criteria of our project and, as previously stated, to provide a workable and superior method of transportation in urban settings, primarily focused on the “last mile” notion.

Figure3.3: Conceived design
The frame was constructed taking into account the normal measurements and typical components in bicycles because it was the sole component intended to be built and conceived from scratch. Making it simple to locate and match the remaining parts, such as the wheels, seat and seat post, headset, fork, stem, and braking system, to the frame.

Costestimation
In this section, we'll estimate the cost of producing this particular bicycle. However, it cannot be predicted with accuracy because some costs, including labour and building processes, among others, cannot be precisely estimated. Nevertheless, we will make every effort to be as accurate and conservative as we can given the unforeseen costs.

Table3.4: Component costs

<table>
<thead>
<tr>
<th>Component</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor</td>
<td>15000–20000e</td>
</tr>
<tr>
<td>Batterypack</td>
<td>160e</td>
</tr>
<tr>
<td>Gearsystem</td>
<td>60e</td>
</tr>
<tr>
<td>Foldingpedals</td>
<td>15e</td>
</tr>
<tr>
<td>Brakingsystem</td>
<td>50e</td>
</tr>
<tr>
<td>Wheelsandrims</td>
<td>40e</td>
</tr>
<tr>
<td>Seat</td>
<td>10e</td>
</tr>
<tr>
<td>Chain</td>
<td>10e</td>
</tr>
</tbody>
</table>
Thereby, the total cost for building and assembling the bicycle, considering generic prices for the components, will be around 3310€.

**PROTOTYPE DESIGN**

This section will describe the model that we created in order to build a completely functional prototype, outlining the model’s primary features and qualities and explaining the decisions we had to make regarding its component parts. We decided to use a frame and parts from an old bicycle because we had to deviate from a frame that had already been constructed. We made an effort to preserve its traditional aesthetics and fundamental aesthetics. By doing this, we hope to create a low-cost prototype that maintains its vintage appearance while being upgraded and restored. In this manner, the end result will build a link between new and antiquated technology in order to produce a superior result.

**COMPONENT AND MATERIAL SELECTION**

**Frame**

As previously mentioned, the scope of our project is limited, thus we won’t be able to create a completely functional prototype like the one we’ve already modelled and presented. As a result, a different design will be offered in this part that takes our restrictions into consideration and considers more practical and realistic alternatives. However, the main features and benefits of the envisioned design will be attempted to maintain in this prototype. It is meant to be constructed using parts from existing bicycles that have been modified to fit our needs and the project’s specifications.

![Figure 3.11: Original bicycle](image)

A mid-drive motor is still the only option in terms of the motor. But in this case, since we are constructing the bicycle from a frame that has already been constructed, we will choose to use a mid-drive motor that will be mounted in the bottom bracket rather than a motor that needs an adjusted frame with special mountings. This makes it simple to fit in the frame and requires few adjustments.

![Figure 3.13: Selected motor](image)

The motor was made by the Bafang company, which has a solid reputation in the e-bike industry. The "Bafang BBS01B" weighs 3.7 kg and has two different kinds of sensors: cadence and speed. The bicycle is powered by 36V and 250W. It has a torque capacity of more than 80 N and an efficiency of more than 80%. The motor includes crankarms, a chain wheel, a speed sensor.
that mounts in the rear wheel, brake levers that are connected to the motor and cut power. When the levers are actuated, a thumb throttle that allows for the management of the motor output and can be used for a "extra push" if necessary. The motor also has a built-in controller and PAS. Additionally, it includes a handlebar-mounted LCD display with three assistance levels that can be used to control the level of assistance provided by the motor. The LCD display also provides additional information such as the current vehicle speed, battery charge, and mileage. This motor features an additional assistance mode that should be employed when the rider dismounts from the bicycle and is moving the bicycle through the handlebars while walking on foot. The motor provides nimble help in this mode, making it easier and less laborious to transport the bicycle.

**Figure 3.14: Handlebar assembly**

Battery

In terms of the battery pack, we have chosen to purchase one that has already been constructed. This choice was made for a number of reasons, including the constraints on building methods and equipment. For example, building a battery pack according to our original design calls for a spot welder machine to connect the batteries, a battery management system, as well as the skills and knowledge necessary to create a marketable product.

**Figure 3.15: Selected battery pack**

The item weighs 2.8 kg and has measurements of 24.5 x 7 x 10 cm. The battery pack that is selected includes a mounting bracket that is used to secure the battery to a tubular support in the bicycle frame. The frame tube is enclosed by the holder, which is bolted to it. Sliding the battery from the holder allows for simple removal. The battery holder also contains a key lock that makes sure the battery is securely fastened and lowers the risk of theft.

36V and 9Ah together produce 324 Wh (324 Wh = 36V x 9Ah). The motor may run for 1.3 hours on a single charge if the battery pack range is predicted using the same calculation method: 324Wh / 250W = 1.3h. With a medium speed of 20 km/h, the predicted range is approximately 26 km (20 km/h x 1.3 = 26 km). As previously stated, this method of estimating the range is cautious and only serves as an approximation because the range is influenced more than just the battery pack's capacity.
A battery, for example, has the freedom to be installed practically wherever on the bicycle when it comes to how the electrical components are distributed throughout the vehicle. Even so, certain parts, such as the throttle, LCD display, and motor, must be attached in particular locations in order to function. We considered a number of aspects while deciding where to attach the battery pack, including its impact on the mass centre, its ease of removal and mounting, its proximity to the motor, and the simplicity of the electrical connections. Since the battery is a relatively heavy component, its location along the framework will have a significant impact on the mass centre of the bicycle and, consequently, on its handling characteristics. This is the factor that we have deemed to be of the greatest importance. The grid behind the seat or above the rear wheel, the seat tube and the top tube, in front of the hinge that folds the frame were other options for where to place the battery. The seat tube was deemed to be the optimum option when taking into account the aforementioned factors. Compared to the other options, it can be put at a lower position, which results in a lower mass centre for the assembly. Due to its proximity to the motor, the wire needs to be shorter, creating a safer connection and simplifying the installation. In any of the possible orientations, removing the battery from the holder would be a simple operation because the holder allows the battery to be removed by simply sliding it to the side.

Handlebar
The handlebar in the previous design could be retrieved into the head tube but it wasn’t collapsible. As a result, we will employ a handlebar with a hinge that moves the handlebar to the side of the front tyre in order to obtain a more compact form when folded. This resulted in a foldable configuration that was much more portable and easy to store. The handlebar can be folded quickly and effectively since the folding system is locked with a quick release skewer. In an effort to maintain the bicycle’s original and timeless aesthetic, we searched for a handlebar that would seem similar to the original but be superior and could enhance the bicycle’s capacity for folding.

Through a conical wedge bolt similar to the one in the figure, the stem (the bottom portion of the handlebar set) is fastened to the headset. In the folded position, it is pressed up inside the hinge, pushing the wedge up and against the interior of the headset to create a tight fix.

Model Description
The handlebar set is made of prated steel, while the majority of the bicycle’s parts are made of an alloy of steel. The frame alone weighs about 10 kg, as shown in the image below, but not including the wheels or the seat and seat post. The weight of the entire bicycle assembly should be roughly 20 kilogrammes, with the battery alone being 2.8 kg and the motor weighing 3.8 kg. However, certain components, most notably the battery pack and the motor, are still missing. The handlebar is the component that determines this dimension, which is roughly 1.40 m long, 1.06 m high, and 56 cm wide when it is installed.

Costs
We will outline the costs associated with producing the prototype in this section. In contrast to the predicted expenses for the imagined model, the costs of producing the prototype can be reduced to the cost of the individual components because the thesis author handled the building procedures and labour.

Table 3.3: Component costs

<table>
<thead>
<tr>
<th>Component</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor</td>
<td>600e</td>
</tr>
<tr>
<td>Battery pack</td>
<td>350e</td>
</tr>
<tr>
<td>Bicycle</td>
<td>100e</td>
</tr>
<tr>
<td>Folding pedals</td>
<td>15e</td>
</tr>
<tr>
<td>Braking system</td>
<td>35e</td>
</tr>
</tbody>
</table>
First, we'll evaluate and contrast both models' compliance with the project's requirements for weight, autonomy, portability, foldability, and safety. The prototype model weighs 20 kg, which is significantly heavier than the anticipated 15 kg weight of the designed model. The primary cause of this discrepancy is the difference in mass density between the raw material's use in making the frames, steel and aluminium. Despite this, the weight of the aluminium and steel frames is fairly considerable, and it is not possible to greatly reduce this weight by using materials that are so widespread and generally simple to work with. In terms of the models’ autonomy, both batteries' capacities—321.9 Wh for the designed model—are relatively comparable. As a result, their range should be similar, but since the aluminium frame is 5 kg lighter, this model should have a wider range. Because the first model enables it to be transported similarly to a trolley, it should be simpler to transport the bicycle once it is folded. It can be recarried similarly to the prototype, although it is more compact and less convenient for the rider. Regarding the capacity for folding, both models offer easy and quick-folding techniques to produce a compact shape. Both models can be collapsed and unfolded quickly and easily with a little practice. The prototype model's folded assembly measures 77 x 29 x 86 cm, while the designed model's folded assembly is 75 x 40 x 77 cm. Therefore, there aren't any big differences between the two. Both frames were structurally analysed using the finite element method, which is why their structures are regarded as safe to use in terms of the models' usability. The prototype model's wheelbase is 90 cm while the conceptual model's is 1 m. This reduces the size of the prototype model slightly when it is installed, enabling easier transportation of the model in this state.

### 3.4 COMPARISON BETWEEN THE TWO DESIGNS

In this section, we'll evaluate the two models' compliance with our project's requirements, compare them, and discuss their key similarities and differences.

First, we'll evaluate and compare both models' compliance with the project's requirements for weight, autonomy, portability, foldability, and safety. The prototype model weighs 20 kg, which is significantly heavier than the anticipated 15 kg weight of the designed model. The primary cause of this discrepancy is the difference in mass density between the raw material used to make the frames, steel, and aluminium. Despite this, the weight of the aluminium and steel frames is fairly considerable, and it is not possible to greatly reduce this weight by using materials that are so widespread and generally simple to work with. In terms of the models' autonomy, both batteries' capacities—321.9 Wh for the designed model—are relatively comparable. As a result, their range should be similar, but since the aluminium frame is 5 kg lighter, this model should have a wider range. Because the first model enables it to be transported similarly to a trolley, it should be simpler to transport the bicycle when it is folded. It can be recarried similarly to the prototype, although it is more compact and less convenient for the rider. Regarding the capacity for folding, both models offer easy and quick-folding techniques to produce a compact shape. Both models can be collapsed and unfolded quickly and easily with a little practice. The prototype model's folded assembly measures 77 x 29 x 86 cm, while the designed model's folded assembly is 75 x 40 x 77 cm. Therefore, there aren't any big differences between the two. Both frames were structurally analysed using the finite element method, which is why their structures are regarded as safe to use in terms of the models' usability. The prototype model's wheelbase is 90 cm while the conceptual model's is 1 m. This reduces the size of the prototype model slightly when it is installed, enabling easier transportation of the model in this state.

### CHAPTER - 04

### PROTOTYPE CONSTRUCTION

The primary challenges we encountered, the modifications or adjustments we had to make to the components, and the procedures we utilised to do it all will be presented in this section. We describe the construction stages that lead to the final prototype.

### MAJOR DIFFICULTIES

We encountered various challenges as we were building and mounting. The frame was the source of most of the issues because it was an old frame with non-standard measurements that needed to be adjusted to work together.

Finding parts that could be adjusted to the dimensions and fastening locations of the bicycle was a major challenge. Components like brake callipers were difficult to come by, and the original bicycle and frame mountings were made to use a horseshoe-shaped brakingsystem, which is no longer in use. Nevertheless, after a thorough search across numerous dealerships, we were able to locate the exact calliper model for which the frame was designed and which was utilised by the factory default. The prototype handlebar was particularly difficult to get because there aren't many vintage bicycles with usable folding handlebars.

A specific washer is needed in the rear hub's internal gear system to lock the hub axle and prevent it from spinning. This washer joins the rear hub axle to the rear dropout; the washer's two parallel faces perfectly fit the axle's two parallel faces, keeping the washer from spinning. Two grooves that fit in the rear dropout must also be present on the washer's outer surface. These washers are essential parts because the gear system wouldn't function without them. The washer that came with the bicycle (the originals from the manufacturer) were extremely worn out and deformed and couldn't fulfil their purpose, so they had to be replaced. Even after a thorough search, we were unable to find the exact washers because they are no longer being produced. Additionally, because they are a very worn-out part, we were also unable to find them on any used bicycles.

In order to make the gear system function properly, we therefore had to construct two of these washers. All of the challenges relating to the construction process and component adjustments were ultimately overcome.

### COMPONENTAL ALTERATIONS/ADAPTATIONS AND PROCESSES USED

Even so, there was a very slight fit issue with the handlebar stem and wedge nut within the headset. The headset didn't have the usual diameter, but the handlebar did because it was part of a more modern model. We chose to use a lathe and remove a small portion of material from the bottom half of the stem and from the wedge nut because it didn't fit by a tiny amount. Less than or equal to one millimetre of material was removed. By carefully and incrementally removing the material, we were able to create a strong and secure connection between the handlebar and the headset.

Due to the non-standard size of the bottom bracket, the motor could not fit. The motor's chainring and the rear sprocket were noticeably out of line when it was assembled in the bottom bracket at its original length. So, to shorten the bottom bracket, we used an electric grinder. To retain the bottom bracket in the middle of the bicycle, the material was taken from both sides. By doing so,
we successfully decreased the chain's misalignment and decreased the risk of the chain jumping off. Several supports that were welded to the frame were also removed using the grinder.

We employed a chemical procedure to remove the old paint and rust from the frame. Pickle liquor is used repeatedly until all of the rust and ink have been eliminated, leaving the frame clean and ready for painting. The paint work was completed in three stages. The first step involved spraying a primer layer using the appropriate ink for this type of application. It shields the metal from rust and provides an appropriate rough surface for the ink to adhere to. The final outcome was then achieved by spraying two layers of black ink.

The handlebar, stem, hubs, spokes, and some embellishments on top of the fork and headset are just a few of the chrome-plated parts of the bicycle. We first sanded and cleaned these with steel wool before treating them. After that, and to get the desired outcome, we used "Duraglit," a metal polish made to eliminate tarnish and provide a glossy sheen.

We began with a solid piece of steel to make the unique washers that prevented the rear axle hub from spinning. We utilised a lathe to give it its rounded external shape, a manual milling machine to make the grooves that fit into the frame dropout, and a borer to make the fitting for the axle. A small square-shaped file was used for the last adjustments and to ensure an flawless fit between the washer, axle, and frame. The washer was constructed, then painted using the same technique as the bicycle frame.

Figure 4.1: Concluded prototype
CHAPTER 5
GLOBAL POSITIONING SYSTEM (GPS)

Due to the fact that they include a power source, e-bikes have special options for tracking usage patterns and understanding how they interact with the urban environment, which could be advantageous for both e-cyclists and traditional cyclists. Understanding how e-bikes are used in particular geographic and cultural situations might assist to comprehend and communicate their potential advantages for sustainable transportation and beyond.

In this paper, the term "e-bike" refers to bicycles with a small motor and battery where riders always have to pedal but can engage electric assistance (often with a choice of low, medium, or high settings) if they so choose. When the pedaling stops or a speed of 15 m/h (25 km/h) is reached, the assistance stops. These electric bicycles, often known as pedelecs, are used in several European nations. There are other e-bike models available, such as ones that allow assistance to be utilized without pedalling; they are very common in several Asian nations, but outside the scope of this study. The models used in this study represent two of the most common motor and battery configurations available for e-bikes: (i) a front-hub motor with a rack-mounted battery; and (ii) a crank-driven motor with a central battery.

Figure 5: GPS

Since tracking moving objects requires battery power, this technology has primarily been applied to moving objects that already have batteries, which are typically motorized vehicles like cars, lorries, boats, or trains. A moving object without a battery, such as a regular bicycle, makes monitoring more difficult because devices cannot draw power from an existing source. As a result, many methods of monitoring bike use have concentrated on the rider's own gadgets (such as their mobile phone) or on mounting long-lasting devices to bikes (such as GPS trackers). Both strategies, while useful in the absence of other options, have drawbacks because they demand compromises in terms of data quality and/or reliability.

The former relies on people carrying their phone on every trip they take (with the relevant application running), while the latter requires a second device to be charged, turned on, and attached to the bike (plus, selecting a setting that increases the device's battery life results in less data being retransmitted). E-bikes include an on-board battery that may be connected to a monitoring system, which records the bike instead of the rider via their phone while maintaining data quality (as is frequently the case in cycling research).

Numerous projects show how to collect sensor data from cyclists. Cycling enthusiasts were requested by Dill and Gliebe [6] to put a GPS device on their bikes and turn it on before each journey. After a period (of at least 7 days), the data was collected from the device. In their 2007 study, 164 individuals rode regular bicycles equipped with GPS trackers for at least 7 days each. In order to evaluate the impact of various types of infrastructure, such as bicycle lanes or trails, on bicycling, the researchers sought to map where cyclists were riding their bicycles in Portland, Oregon. The researchers used a GPS personal digital assistant called the Garmin iQue, which was set to gather extra data from trial participants regarding the route and the associated weather that had to be manually entered for each trip. For each journey, the device had to be mounted on the bike (different mounting for each type of bike). The device's memory card was used to store the data. Following the device's collection, the researchers analyzed and visualized the data. Then, trial participants accessed maps of all their trips through an online interface and were asked to provide more details for each trip. Trial participants had to put in a significant amount of effort to do this.

Both the Biketastic and UbiActive experiments solely used the phone's built-in sensors and employed Android programmes that were installed and running on the participants' own phones. The Copenhagen Wheel went a step further by using Bluetooth sensors mounted on the bicycle to connect riders' phones. Paefgen and Michael demonstrated how a monitor could operate independently utilizing electricity from the e-bike battery, although these modules are only capable of GPS sensing. A nice illustration of how to use a mobile device as the focal point of a monitoring system is the BikeNet project.
The Campus Mobility initiative also kept track of e-bike usage on a college campus. They made use of a GPS module installed on the bike and a small Android touchscreen computer. There are a number of public bike programmes that track utilisation data in real-time, however they depend on parking and charging facilities. E-bike rental programmes exist in countries like Germany and the Netherlands, as well as in the San Francisco Bay Area, the University of Tennessee-Knoxville, and a future pilot programme that will integrate with a car-sharing company. While most hireschemes do not collect data on the actual journey between stations, many do record data when bikes enter and exit parking stations. Instead of GPS data of the actual path travelled, the trip data used when analysing the movement of bikes in public hireschemes usesthe location and time of the station at the start and conclusion of each trip.

Figure 5.1: Smart E-Bike
HARDWARE DESIGN
An Android phone, an open hardware interface board, and a custom power board to connect the system to the e-bike battery make up the three primary parts of the SEMS hardware. The circuit diagrams for the unique power board for the Dover bicycle and the Velo-cité are shown in Fig. 4. Behind the bike rack, all components are kept in a small water and dust-proof box. A description of the hardware in the monitor system, SEMS is built around an IOIO board and an Android phone. The IOIO is a cheap interface board that attaches to the phone using the USB port. It supports a variety of digital input/output protocols and analogue inputs for connectivity with a wide range of sensors. Communication between a board and a phone is made possible via an Android software library. The benefits of the Android application programming interface (API) and phones sensors, such as the GPS and accelerometer, are provided by this combination, which also makes it possible to customize the hardware in a very flexible way using the IOIO box. Importantly, the system can operate continuously without human intervention thanks to the IOIO's ability to be powered by the bike battery, which can then recharge the phone.

PHON SELECTION
Several Android phones were evaluated in order to determine which one would serve as the central hub of each monitoring system. Low cost, boot-on-charge capability, GPS signal quality, third generation (3G) connectivity, and long battery life were the main requirements. To meet the design objective of autonomous operation for SEMS, a phone needed to be able to boot up automatically (without user assistance) in a situation where it had run out of battery (for any amount of time). Restoring the power source was necessary to restart the phone and start the SEMS app in addition to automatically starting the phone to recharge (i.e. attaching a charged bike battery to the e-bike). This was done to account for scenarios where the participant would drain the bike's battery or take the phone off the bike, which would result in the phone running out of battery. When trial participants weren't using the e-bike for prolonged periods of time—for example, due to holidays or sick days—problems arose from an initial design that used mobile phones that don't reboot. As a result, this functionality became the main criterion for choosing a gadget. Finding a cheap Android phone with boot-on-charge functionality was tough, but after some trial and error, a phone was discovered that, after rooting and tweaks to low-level operating system functions, would do this consistently.

CHAPTER-06
CONCLUSIONS AND FUTURE WORK
The goal of this project was to design and construct an electrically assisted bicycle that was suitable for urban environments. The idea was to develop a more efficient and adaptable mode of transportation for urban environments. It should be designed to have advantages and superior characteristics above the standard options, such as public transportation, private automobiles, or regular bicycles. The project was designed to streamline and facilitate movement in large urban areas, but it was already primarily intended to be used in the "last mile" idea. A study on the electric bicycle market was conducted, and the results showed that sales of these vehicles have increased significantly and exponentially over the past several years. It was shown that electric bicycles will undoubtedly be used in the future for a variety of applications, not just in urban settings. Growing environmental concerns and technological advancements were two of the key factors that contributed to the market's current level of prominence.
A survey was conducted with the goal of defining the primary needs in order to create a product that represents a workable option as a mode of transportation and is primarily focused on the "last mile" idea. These specifications, which were taken into consideration, are essential qualities and aspects that the bicycle should have. They are: autonomy, weight, ease of transportation, practicability, and safety. We might then move on to project and construct a feasible solution from these fundamental components. A bicycle, or an electric bicycle, is made up of a number of parts, all of which must be carefully picked in order for them to work together harmoniously and produce a workable and viable solution. Being an ancient mode of transportation, bicycles and the components that make them up have undergone significant evolution. Consequently, there are numerous options available for the various parts that make up a bicycle. On this basis, we evaluated them and component possibilities in order to select a system that would serve our needs and be able to produce a workable set.
Due to the project's restrictions, as previously mentioned, we created two distinct designs: one that was created from scratch without much consideration for the limitations set forth, and the other that was created to be built and serve as a fully functional prototype for the
project. Using CAD software, the structural validity of both models was verified. The construction procedure could start after the structural validity and component selections. The finished product displays a completely functional prototype that serves as a realistic transit option in a city setting. The prototype was constructed using recycled bicycle parts, and as a result, we were able to produce a product that bridges the gap between the past and the present by combining a traditional-looking bicycle with modern improvements.

Improvement and reinforcement of the design, as well as consideration of other options that may be more suited, to hold the bicycle in the folded position, would be future work and development of this project. Regarding the raw material used, there are various alternatives that can be considered, including lighter and more suitable materials like carbon fibre.

With the help of this research, it was feasible to draw the conclusion that bicycles, and more specifically, electrically assisted bicycles, have played an essential role as a mode of transportation and will likely continue to do so because they are constantly improving. Electrical bicycles are a notion that is intended to expand and broaden its field of use as technology improves and breakthroughs. With the help of this effort, we were also able to draw the conclusion that although the technology that supports the notion has advanced greatly, it still has significant limitations. This largely pertains to the batteries because they are an essential part that reduces the bicycle’s range and increases its weight, which are two needs taken into account for the project. As batteries continue to be updated, it is anticipated that these significant drawbacks will be resolved in the near future thanks to technological advancement. Additionally, new and more effective motors are beginning to be developed, along with retroactive systems that enable battery recharging while the bicycle is being used.

REFERENCES: