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1 Problem Formulation

1.1 Introduction

In Phase 1 of the design discussion, Team Techne developed an objective statement along with a Black Box model displayed in Figure 1.1. This model will feature a concise, broad description of the design process and the desired impact that the project will have on those interesting in producing renewable energy upon completion. The GBike is a module that is mounted to a bike and harnesses the rotational energy of the wheels to generate electricity. The original design was brought to life by Sam Russak, and his teacher Brennan Legasse of Sierra Nevada College. The GBike was created to provide those without electricity in essentially any circumstance, with a way to generate their own.

1.2 Objective

The objective for this project is to create a viable bicycle-based product that can produce renewable energy by pedaling, which can be stored to power electronics.

1.3 Black Box Model

The black box model, as shown in Figure 1-1, defines the state of the world before and after the completion of the bicycle-powered charger.

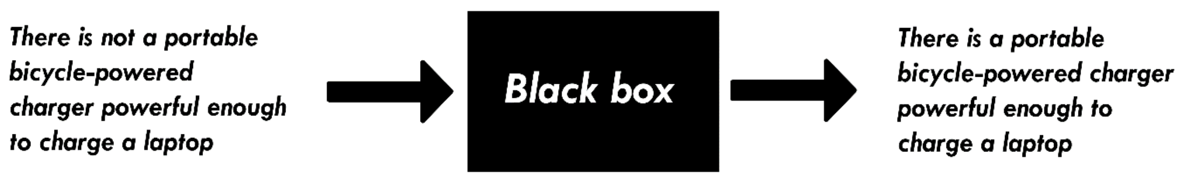

Figure 1-1 Black Box Diagram

2 Problem Analysis and Literature Review

2.1 Introduction

This section covers and reviews the specifications of the problem and the research done on various topics related to the problem.

2.2 Problem Analysis

2.2.1 Introduction

The purpose of the problem analysis is to review the defined criteria set by the client and to establish the specifications, considerations, criteria/constraints, intended usage, and production volume.

2.2.2 Specifications

Our client was very adamant about the lack of specifications given to us prior to designing the project. His only specifications were that we design a system that is added onto a bike that generates and stores electricity and can be set up and used by any regular person who are given instructions.

2.2.3 Considerations

While designing this project, we must consider the final purpose for this project which is to act as an educational aid and an example of a sustainable solution for those who are subject to unreliable power. This design may also be developed and deployed which we must put into consideration.

2.2.4 Criteria/Constraints

Safety	**9**	System is safe to user.
User Friendliness	**9**	Easy to assemble and repair.
Adaptability	**7**	Will fit to virtually all bikes.
Transportability	**7**	Ability to adjust components.
Power	**6**	Must produce at least 100W.
Sustainability	**5**	More than half recycled materials.
Aesthetics	**4**	Clean Design.
Cost	**3**	Time and money spent.

Figure 2-1 Criteria and Constraints

2.2.5 Usage

The mobile bicycle generator will be used in areas without a reliable source of power, be it somewhere with low infrastructure, such as a developing country, or places prone to frequent power outages. The bike can still be used for transportation with minimal-to-no hinderance to the user when the system is disconnected.

2.2.6 Production Volume

One prototype system will be assembled that attaches to a bike to generate and capture energy in a battery for later use. Only one system is needed for this project. However, the design is intended to serve as a template for future development of the system.

2.3 Literature Review

The purpose of the literature review is to gather relevant outside information, define technical terms, and discuss what the current state of the technologies are.

2.3.1 Lighting and Green Screens

2.3.1.1 Lumens and Other Basic Terminology

A lumen (lm) is the SI unit for the measure of total visible light in an area produced by a light source and calculates the amount of “luminous flux, the total amount of light emitted in all directions” (Wave Form Lighting). As the measurement gets higher, the more light is being produced by the light source. (Integral LED). Contrary to popular belief, lumens and watts (a unit of power) are not necessarily correlated and light sources can have a high wattage without high lumens if the energy is lost through heat. A helpful measurement that is used to display efficiency in a lightbulb is Lumens per Watts (lm/W) which shows how much light is being produced for every watt of energy. (Integral LED). According to Today's Homeowner, a standard 60-Watt lightbulb produces about 750 – 800 Lumens of light.

A lux (lx) is equal to one lumen per square meter and measures the light density and intensity caused by a light source onto a surface. Because light spreads and gets dimmer the further away a surface is from a light source, distance is needed to be mentioned when calculating lux (i.e. 2000 lux at 10 feet). This is important for photography and other situations in which lighting on a surface needs to be optimal and consistent.

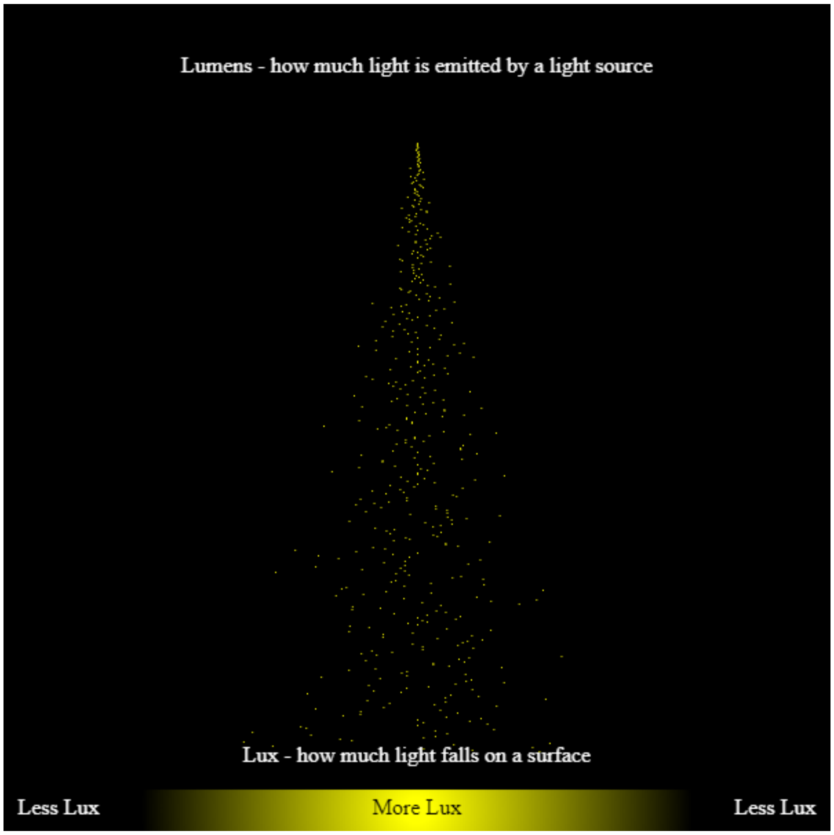

Figure 2-2 Wave Form Lighting (Reproduced from Waveform Lighting,2020)

2.3.1.2 Different Types of Lighting

Figure 2-3 Images of different bulb types (Reproduced from Missouri's Electric Cooperative, 2020)

2.3.1.2.1 Incandescent lightbulbs

Incandescent lightbulbs are one of the most commonly used type of light bulbs used today and are one of the oldest designs of lightbulbs. This bulb was invented around 130 years ago. (Cangeloso) An incandescent bulb consists of a bare wire that is heated up by electricity coursing through it protected by a glass bulb. The energy is released as heat and light energy, thus creating a light source. When lit at the suggested wattage, an incandescent bulb loses almost 90% of its energy to heat, making its lumens/watt ratio very low in comparison to other lightbulbs. Because of the heat energy being releasing, this type of bulb also has the shortest lifetime, around 1,200 hours according to Viribright. This life span can be lengthened by up to two times as long with only a 5% wattage reduction. However, incandescent bulbs are on average much cheaper than any other light bulbs and produce a warmer light than those of LED or CFL which are thought by some to be artificial and unattractive lighting. (Cangeloso)

2.3.1.2.2 LED lightbulbs

LED lightbulbs produce their light through the use of semiconductors. A semiconductor is a solid material that acts as both an insulator and a conductor to electrical currents. The semiconductors in LED bulbs create light by running a forward current through the semiconductor, which is typically made out of gallium arsenic, causing the bulb to emit light. LED stands for Light Emitting Diode. LED lights have the longest lifespan of the 3 types, lasting up to 25,000 hours and do not immediately die out all at once but instead slowly decrease its lumen to watt ratio. It also has the highest lumens to watts ratio as seen in Figure 2-3. The price of the LED light also has the highest cost of the 3 bulbs at a low of $4 but can cost much more depending on brand and quality. (Cangeloso)

2.3.1.2.3 CFL Lightbulbs

CFL stands for Compact Fluorescent Lamp and consists of a bulb containing a tube filled with argon and small amounts of mercury. These elements react when exposed to electricity and creates ultraviolet light which then reacts with fluorescents called phosphors creating visible light. CFLs are known to have around an 8,000-hour lifespan, according to the ViriBright website, which is significantly larger than incandescent bulbs. These bulbs cost on average about $2 when sold in packs and produce the same number of lumens with a 15W bulb as a 60W incandescent bulb which can be seen in Figure 2-3. The major drawback with this type of lighting is the complications involved in disposal because of the mercury contained inside the bulb. The mercury can also pose a threat to health if the bulb becomes corrupted. (Cangeloso)

Lumens (Brightness)	LED Watts (Viribright)	CFL Watts	Incandescent Watts
400 – 500	6 – 7W	8 – 12W	40W
650 – 850	7 – 10W	13 – 18W	60W
1000 – 1400	12 – 13W	18 – 22W	75W
1450-1700+	14 – 20W	23 – 30W	100W
2700+	25 – 28W	30 – 55W	150W

Figure 2-2-4 Lumen Rating for various bulb (Reproduced from ViriBright, 2019)

2.3.1.3 Green Screens

Green screens work by a process called Chromakey which is a software that isolates a certain hue of a color (usually the bright green on a green screen) and eliminates the specified hue in a picture or film. This creates a blank background that can be switched out with any background the director desires. The typical green hue that is used in green screens was chosen because the color is almost never seen on humans naturally and is a mostly uncommon color to use on clothing. (Weisberger)

In order for green screens to work, consistent lighting without shadows is required. Shadows slightly alter the color of the green screen and the camera cannot pick up on the color as well creating a lower quality rendering (Weisberger). To create good image quality, the lux needs to be high and consistent throughout the greenscreen and on the subject itself. Two lights in front of the subject at 45-degree angles is suggested to create even lighting with backlighting on the greenscreen itself to eliminate shadows as much as possible. To prevent concentrated lux in one area, or “hot spots”, using sheets to cover the lights to create soft lighting is preferred. (Kroll)

Figure 2-5 An example of "Soft Lighting" (Reproduced from Kroll, 2016)

2.3.2 Possible Methods of Transport

2.3.2.1 Wheels

Iron caster wheels are generally used on tracks to minimize friction and increase efficiency. Because they are made of metal, iron caster wheels are not optimal for any off-track travel. The metal increases shaking while movement, does not get traction in dirt, and are heavy. The durability of metal is much higher than rubber, however. These wheels cost around 25$ on Amazon.com.

Rubber inflatable wheels are designed to handle rougher terrain than the other two-wheel types because the rubber and the tube acts as a buffer between the cart and the ground creating suspension. A downside is that the tires can pop or become flat which can jeopardize the device by making the wagon tip over. The durability of the wheels is also lower than the other two options. These wheels cost anywhere from 15-30 on Amazon.com.

Rubber caster wheels are ideal for rolling on concrete, cement, or any even surfaces. These wheels are much more durable than the inflatable wheels but also have a slight suspension because of the rubber material. They do not perform well on dirt or uneven surfaces, however. These wheels cost about 27$ on Amazon.com.

2.3.2.2 Carrying

This method involves picking up the device and carrying it to the location. The base of the device would need to be strong enough to support the weight of the device while also being resistant to tipping. This method involves the most risk because of the possibility of dropping the device.

2.3.3 Batteries

Batteries come in an incredibly wide spectrum of capacities, chemistries, and appropriate use-cases. For instance, a small-capacity battery designed for a lightweight drone would be completely unsuitable for deployment in a large warehouse for use in an uninterruptible power supply system. Therefore, batteries for use in a photovoltaic system are largely designed with the specific end use-case being to store bulk amounts of energy, have large amperage outputs, and generally pay little concern to weight or volume occupied. Generally, an individual creating a residential-grade photovoltaic system with a battery bank has access to a relatively small range of battery chemistries.

2.3.3.1 Lead-Acid

One of the oldest and most ubiquitous battery chemistries available to consumers is the traditional lead-acid battery, "in which the electrodes are grids of metallic lead-containing lead oxides that change in composition during charging and discharging," (Figure 1) (Northern Arizona Wind & Sun, n.d.). These batteries are most commonly used as car batteries due to their relatively low price compared to other technology types, high-amperage delivery for use in the starter motor, and reasonable energy density for the application. These batteries, for similar reasons, are commonly deployed in small-scale photovoltaic systems in which the end user does not need extraneous amounts of energy, as would an industrial or business application.

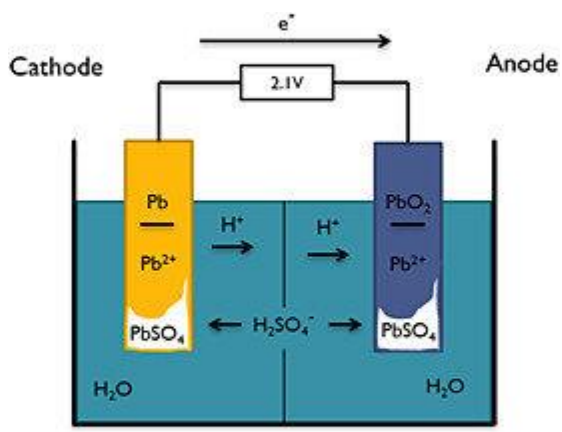

Figure 2-6 Lead-acid battery chemical reaction (2015)

2.3.3.2 Lithium Ion

The next most common battery chemistry in photovoltaic systems is the lithium ion cell, in which lithium ions flow through an electrolyte from an anode (positive side) to a cathode (negative side), where the extra electrons lost in the reaction flow through a wire and power a connected load (Energy.gov, n.d.). Lithium ion cells are widely deployed in consumer electronics due to their high energy, density, relative light weight, and low energy drain over time. However, for small photovoltaic applications they are generally less favorable than lead-acid batteries due to their short lifespan (2-3 years, compared to ~10 years), high susceptibility to harsh environments, and possibility of a fire hazard if not managed properly by appropriate charge controllers and battery management systems (BMS) (Brain, 2006). This chemistry of battery is much more favorable for an industrial or grid-power end use-case due to high overall cost but equally high performance and energy density, with Tesla being the most commonly recognized company developing large-scale lithium ion storage systems with their Powerpack line of products (Tesla, Inc; n.d.). Popular consumer-grade styles of this battery include button cells

(Figure 2, style B), pouch cells (hobby batteries, more commonly found as lithium-polymer chemistry) (Figure 2, style D), and cylindrical cells, such as the commonly-found 18650 cells (named for their dimensions: 18 by 65 millimeters, usually found in removable laptop batteries) (Figure 2, style A) (Battery University, 2019).

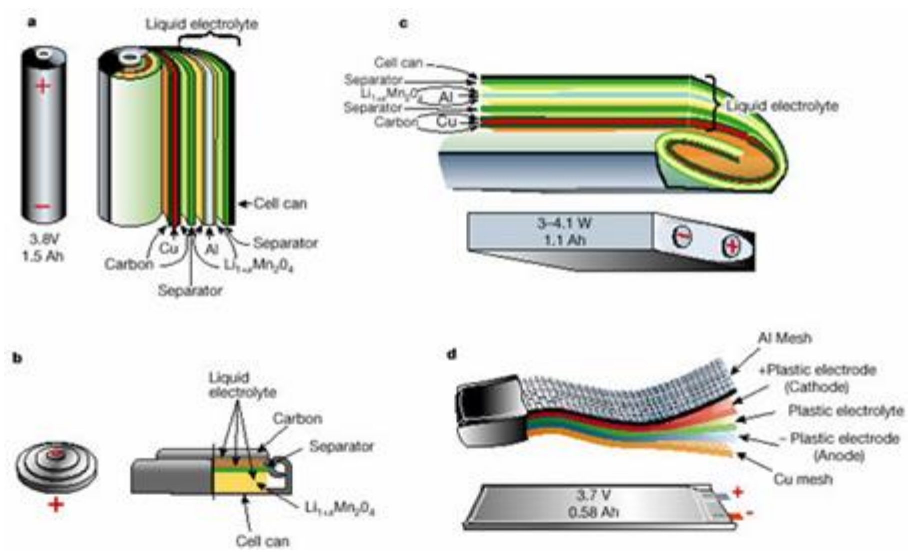

Figure 2-7 Common Li-ion battery styles (2001)

Typically, high-quality lithium ion cells have a built-in BMS that prevents hazardous situations from arising along with other additional safety mechanisms such as thermal fuses which self-destruct when a set current is exceeded or safety vents that prevent the explosion of a cell by allowing the release of gases if necessary (P.G. Balakrishnan, R. Ramesh, T. Prem Kumar; 2006).

2.3.4 Electrical Safety

In the discussion of high-power photovoltaic systems, and even moderate-to-low power systems, it is vitally necessary to discuss electrical safety in installation and, in lesser frequency, everyday use. Trained electricians understand the core concepts of electricity and its effect on the human body if used improperly or irresponsibly and take steps to avoid encountering such scenarios. In Figure 3, a chart demonstrates the differences between different currents running through the human body, which range from “faint tingle” to “death probable” (Fowler, T. W., Miles, K. K., 2002). However, it is important to note in this figure where it describes that a standard household circuit breaker trips at 15 amps, which is five amps higher than a current that could cease regular heart functions and cause nerve damage. When working with photovoltaic systems, it is incredibly important to take steps to ensure that the current does not pass through your body to the earth, such as wearing shoes that isolate you from ground, not wearing metal objects, such as rings, on your hands or arms, and, to prevent damage to the electronics themselves, wearing proper electrostatic discharge equipment when appropriate as to not damage circuitry you may be working on.

Effects of Electrical Current in the Human Body[3,4]

Current	Reaction
Below 1 milliampere	Generally not perceptible.
1 milliampere	Faint tingle.
5 milliamperes	Slight shock felt; not painful but disturbing. Average individual can let go. Strong involuntary reactions can lead to other injuries.
6–25 milliamperes (women) **9–30 milliamperes** (men)	Painful shock, loss of muscular control. The freezing current or "let-go" range. Individual cannot let go, but can be thrown away from the circuit if extensor muscles are stimulated.*
50–150 milliamperes	Extreme pain, respiratory arrest (breathing stops), severe muscular contractions. Death is possible.
1,000–4,300 milliamperes	Rhythmic pumping action of the heart ceases. Muscular contraction and nerve damage occur; death likely.
10,000 milliamperes	Cardiac arrest and severe burns occur. Death is probable.
15,000 milliamperes	Lowest overcurrent at which a typical fuse or circuit breaker opens a circuit!

*If the extensor muscles are excited by the shock, the person may be thrown away from the power source. The lowest overcurrent at which a typical fuse or circuit breaker will open is 15,000 milliamps (15 amps).

Figure 2-8 Table of electrical currents and effect on the human body (2002)

2.3.5 Similar Projects

2.3.5.1 Basic Solar Lighting Projects

Projects generally consist of the following basic components: Solar panels, a charge controller, a battery, a lighting controller, a lighting system, wires, and other electrical components.

The first project researched was a LED solar lighting system for outdoors. This project mostly had to do with connecting preassembled pieces. Parts for this project included: cheap lighting system for the lighting units, heavy duty outdoors wire, 3 watt LED's, a LED driver, heat sinks, a 18V solar panel, a 12V solar charge controller, a 12V battery, wire, a plastic container, washers, a cable clamp, a terminal strip, a PNP transistor, a prototyping board, a 10,000 Ohm resistor, and a diode. Tools included: a soldering iron, screw drivers, silicon calk, a wire stripper, and a wore cutter. The estimated time and cost for this particular project was $75-$100, and 2-3 hours. To create this system, take apart the cheap lighting system, gutting it for the lighting units. Next, thread new wire through the units, soldered on the LED's, and reassembled the lighting unit. Then create an encloser for all the wiring and circuitry by burning a hole in a plastic tub and installing cable clamp and a rubber washer to hold the wires and help prevent water from getting in. Then proceeded by wiring everything together: cutting wire and attaching it to the terminal connector to use with the battery, connecting the positive and negative wires to the battery, taking more wire and attaching it to the positive and negative load terminals of the charge controller, attaching those wires to the terminals on their LED driver, connecting the LEDs to the driver via terminal strip, taking a positive wire from one of the lights and connecting it to the strip, taking the negative wire and putting into another terminal, taking the positive wire from the other LED and putting it in the same terminal as the other positive wire, and connecting the last negative wire to the LED driver to complete the circuit. Then testing the system and putting circuitry into the enclosure and connecting the solar panel to the charge controller as their last step (Instructables, 2017).

The second project research was another lighting system for outdoors. This system included a 22-watt LED, a LED driver, a direct burial wire, a charge controller, and a solar panel. Tools used include: wire strippers, a crimping tool, and a screw driver. The website didn't include very good instructions for setting the system up, but it did provide a diagram that it useful for visualizing how the pieces of the project might connect together (Heideman, M. 2012).

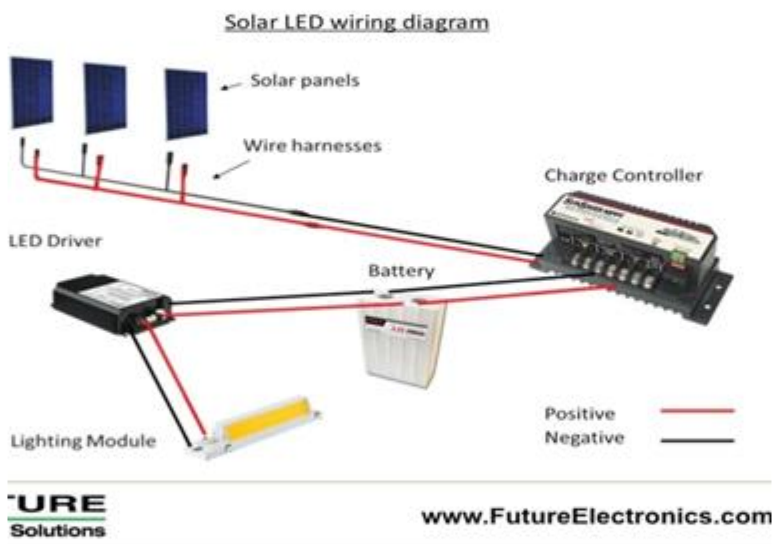

Figure 2-9 Depicting a Solar Lighting System (Heideman, M. 2012)

The third project researched was DC-DC Converter for Harvesting Energy from an Exercise Bike. The goal of this project was to create an efficient buck-boost converter that would help harvest energy from exercise machines in the Cal Poly gym. The machines input voltage ranging from 3.8V to 70V. This voltage needs to be adapted to outputs of 13.7V DC, the voltage required by a charge controller to charge a battery. The job of the project was to design an electric system that would boost voltages coming at 0V-13.6V to 13.7V and buck those voltages from 13.8V-60V so that the battery can constantly charge during the entire duration of a user's workout (Ureh and Henry 2009).

2.3.5.2 How to be Educational

A way to make the project more educational is to build it in such a fashion that anyone can use, operate, and maintain it. Create something that is intuitive for people to use and that something that people are interested in using.

2.3.5.2.1 Pedal Power Generator Stand

A project researched to see how others have made their projects educational, was a pedal power generator belt stand. An example of this type of design is shown by figure 2-10. This system can be used with a full-sized bicycle or a small bicycle for use by either an adult or a child. The system outputs DC voltage so it can be used to charge 12V lead acid batteries or 12V power packs. This is system is ideal for teaching kids about possible ways to generate electricity because it allows them to interact with the system (Petal Power Generator).

2.3.5.2.2 Spin Bike Generator System

The next project researched was a twelve-person spin bike generator system. In this system power fed from each bike to a power monitoring electrical box which combines the power from each bike, the power then runs through a charge controller and inputs into a 12V battery. This type of project allows the public to be educated about a renewable energy by interacting with a system that generates power from humans exercising (Petal Power Generator).

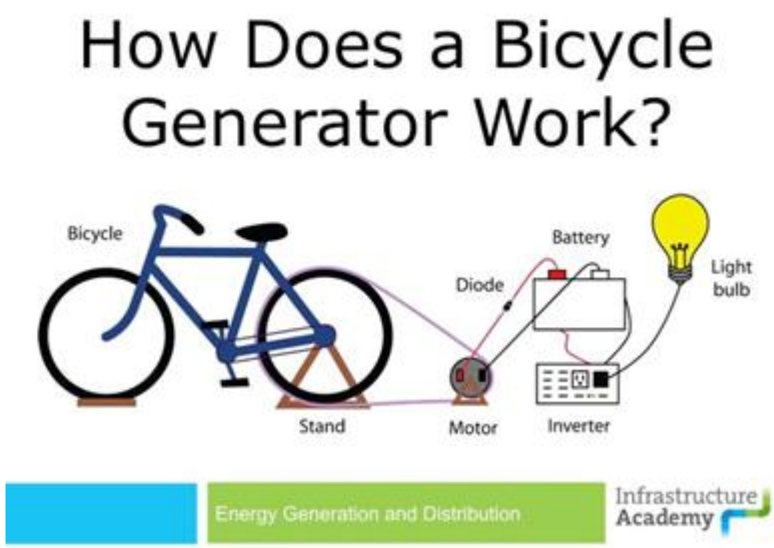

Figure 2-10 Simple example of a Bicycle Generator System (Instructables Bicycle Generator Diagram)

2.3.5.2.3 Bike Generator with Attachments

Another project researched was bicycle generator project done by Northern Arizona University. This project was created to teach students about fundamental concepts of energy and basic mechanical, engineering, and electrical principles. The generator was used in the classroom as a hands-on and fun activity to help understand these concepts. They used the generator to light up a bulb, run a hair dryer, and power a leaf blower that kids used to try and keep a ball in the air (Bicycle Generator Project).

2.3.5.2.4 Geared-Up from the Feet-Up Project

Another project researched was the Flock House Geared-Up from the Feet-Up ENGR215 project from 2011. The team designing the project was put to the task of designing a bicycle powered generator capable of generating 100+ watts while keeping the option of type of bike used for the system open. The teams final design included a charge controller, a 36V DC motor, a 12V DC light bulb, a derailleur, a plexiglass box, a customized roller, and a bike trainer stand. The objective of the team was to design the project as learning tool to educate Flock House visitors about alternative energy generation (Blader, Bivens, Rowe, Stufkosky 2011). Figure 2-11 shows their design.

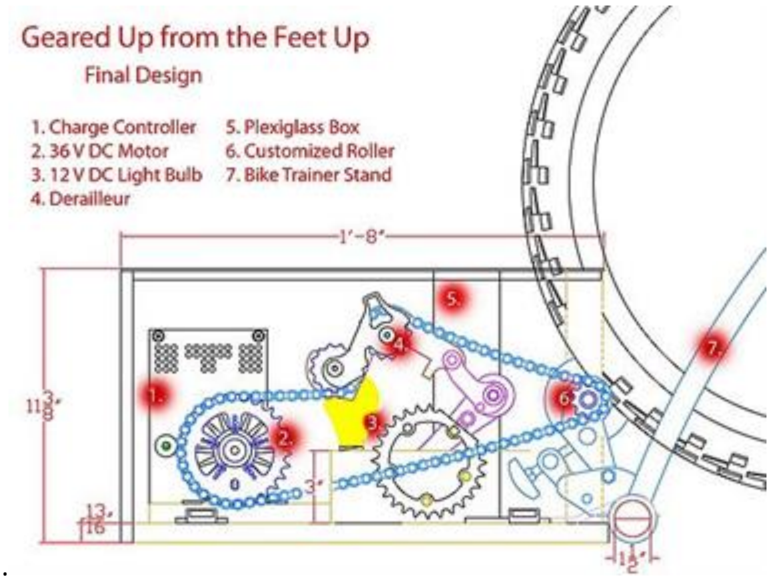

Figure 2-11 Geared-Up from the Feet-Up Project Design

2.3.6 Sustainability

Sustainability is the avoidance of the depletion of natural resources while keeping ability of the system to be maintained (Lexico Dictionaries, 2020). Sustainability energy can be defined by meeting the following criteria: not depleted by continued exploitation, not causing harmful emission of pollutants or other negative impacts on the environment, not causing human health hazards, and the harnessing or trading of them does not cause and/or perpetuate social injustices (Ehenhack and Martínez, 2013). Creating a sustainable project can be achieved by finding secondhand materials to re-use or re-purpose, as well as building something that can be easily maintained. Another way to add to the sustainably of a system is to build a project with parts that can be easily detached and replaced. The system itself will also promote sustainability because it allows a user to create power from a renewable source. When looking for secondhand parts, places like Arcata Scrap and Salvage could be used as resources.

2.3.7 Solar Energy

2.3.7.1 General Definition

Solar energy is one of the most common forms of renewable energy. Developed in the 1950's, solar energy is widely used as a consistent, and clean energy producing method. Currently, consumer grade solar panel efficiency is rated at 22.8% for the absolute most efficient. Most solar panels, however, are between 15-20%. To put this in a better perspective, Energysage provides this explanation of solar efficiency: "...For two solar panels of the same physical size, if one has a 21% efficiency rating and the other has a 14% efficiency rating, the 21% efficient panel will produce 50% more kilowatt-hours (kWh) of electricity under the same conditions as the 14% efficient panel."(energysage.com). The most common way energy is produced through solar is called Photovoltaics, which can be abbreviated as PV. To put it simply, this is done through PV cells converting solar radiation into electricity (pveducation). The solar voltaic cells are made of a positively and negatively charged film of silicon, each placed on a very thin slice of glass. As the sun beats down on these cells, the photons emitted "push" the electrons from the silicon. These electrons are then attracted to one side of the cell and can be harnessed as a voltage (nwwindandsolar). Each cell produces a small amount of voltage, which is why they are placed together in an array, leading to the creation of a solar (photovoltaic) array. It is important to note that the current produced by these arrays is DC (Direct Current), which needs to be changed to AC (Alternating Current) through an inverter if necessary.

2.3.7.2

Solar energy is one of the most common forms of renewable energy. Developed in the 1950's, solar energy is widely used as a consistent, and clean energy producing method. Currently, consumer grade solar panel efficiency is rated at 22.8% for the absolute most efficient. Most solar panels, however, are between 15-20%. To put this in a better perspective, Energysage provides this explanation of solar efficiency: "...For two solar panels of the same physical size, if one has a 21% efficiency rating and the other has a 14% efficiency rating, the 21% efficient panel will produce 50% more kilowatt-hours (kWh) of electricity under the same conditions as the 14% efficient panel."(energysage.com). The most common way energy is produced through solar is called Photovoltaics, which can be abbreviated as PV. To put it simply, this is done through PV cells converting solar radiation into electricity (pveducation). The solar voltaic cells are made of a positively and negatively charged film of silicon, each placed on a very thin slice of glass. As the sun beats down on these cells, the photons emitted "push" the electrons from the silicon. These electrons are then attracted to one side of the cell and can be harnessed as a voltage (nwwindandsolar). Each cell produces a small amount of voltage, which is why they are placed together in an array, leading to the creation of a solar (photovoltaic) array. It is important to note that the current produced by these arrays is DC (Direct Current), which needs to be changed to AC (Alternating Current) through an inverter if necessary.

2.3.7.3 Types of Solar Energy Production

There are two main types of solar energy: Solar Photovoltaic (Which was explained prior), and Concentrated Solar Power CSP. To touch on again, Solar PV energy is derived from the solar radiation beating down from the sun. This is utilized by a positive-negative charged film of silicon on a small film of glass, that has its electrons excited/moved by the photons emitted from the sun (pveducation). Concentrated Solar Power, however, does things a little bit differently. CSP focuses on the heat emitted from the sun, and functions by the collection of a high concentration of heat from the sun. This is commonly seen in large solar power plants and is done so with a vast array of mirrors. According to planete-energies.com, the Ivanpah California plant is the largest concentrated solar power facility and has a capacity of 392 MW. The concentrated heat that is directed by the mirrors is used to heat a "transfer" fluid. This fluid can be water, oil, molten salt or organic liquids such as butane or propane (though is most commonly molten salt). This fluid is transferred, then, to a network of water which produces steam from this heating, powering turbines (planete-energies). In these plants, there is usage of hundreds, and sometimes upwards of a thousand mirrors in use to redirect the sunlight. The mirrors are mounted on heliostats (an apparatus containing a movable or driven mirror, used to reflect sunlight in a fixed direction), which point the mirrors toward a central tower.

Figure 2-12 Heliostat at Thémis Experimental Station in France

These towers, sometimes larger than 200 meters tall, are fixed with a receiver at the top. This is the area in which the heliostats direct the concentrated sunlight and carries the easily heatable transfer fluid (planete-energies). Though, to get these plants to maximize their output, the location must be specific. It must be in a large flat expanse of land, with a massive amount of direct sunlight directed towards it. Take, for example, the prior mentioned Ivanpah plant in California. This plant is located in a desert and uses about 173,500 heliostats (planete-energies). This location is one of the best possible scenarios for this type of plant and works great where it is. But this is just not practical in most locations, say on top of a house or a business. Therefore most, if not all consumer solar panels are Photovoltaic cell array panels.

3 Search for Alternative Solutions

3.1 Introduction

Alternative solutions for Team Techne's bicycle generator have been developed through multiple sessions of collaborative brainstorming involving all four members of the team since the beginning of the project. These solutions are designed based on the specifications and vision of the client while also trying to create new and creative ways to design the project. A total of eight alternative solutions were developed. The designs will be used to find a final design to pursue.

3.2 Brainstorming

Team Techne met for multiple short brainstorming sessions in which all team members shared and discussed their visions for the project. From these visions, the team was able to build and branch off from each idea and come up with viable solutions to the problem. After all ideas were exhausted, these eight solutions were drawn up and assigned to a team member to sketch, describe, and evaluate. The list created in our initial brainstorm can be found in the figure below.

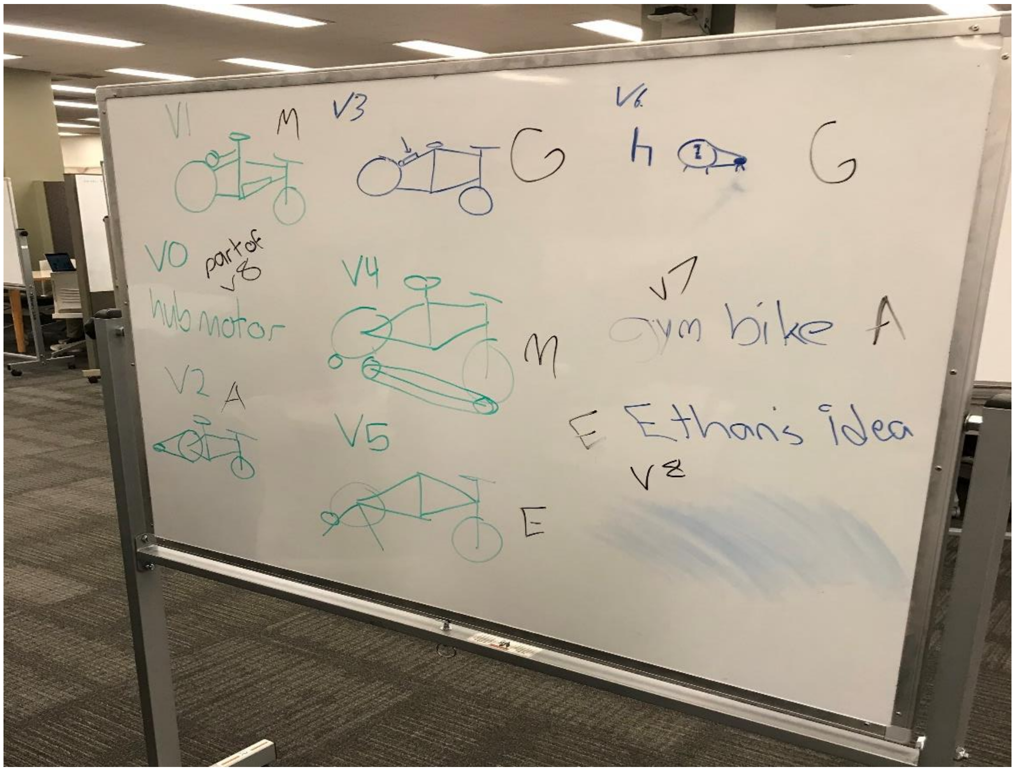

Figure 3-1 Brainstorm for Alternative Solutions

3.3 Alternative Solutions

This section describes different possible prototypes for the GBike. There are 8 total drafted prototype variations for the GBike listed in the sections below.

3.3.1 Attachable Friction Motor (V1)

As seen in figure 3-2, this Friction Motor involves an attachable system composed of a battery, a voltage regulator, and an alternator that can be adapted to fit almost any bicycle. The battery attaches to the frame in the location of the water bottle holder and is be attached in the same way as the bottle frame. The battery is connected via the voltage regulator to the alternator which would be held by a frame that connects to the seat post. The frame is adjustable to allow the user to create friction between the alternator and the tire, or the alternator could be loosened and moved into a storage mode to allow the rider to ride without resistance.

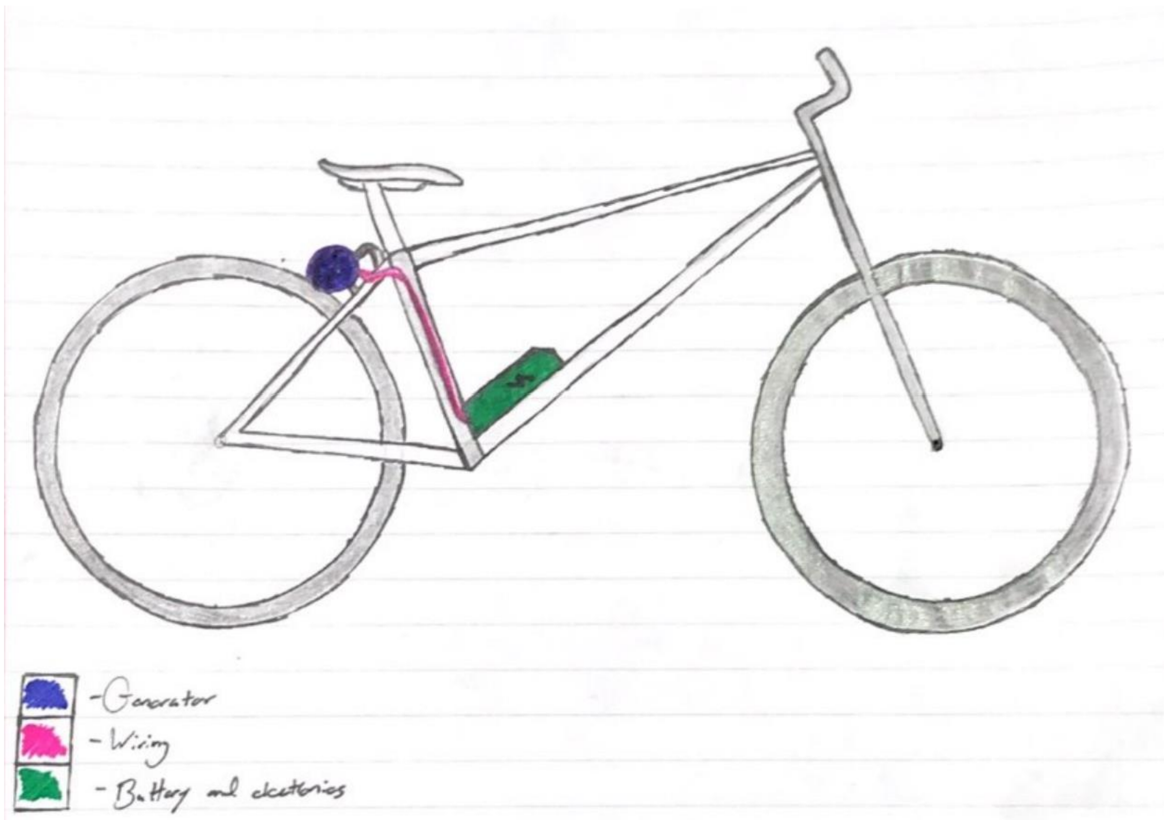

Figure 3-2 Drawing of V1 Attachable Friction Motor

3.3.2 Pulley Wheel w/ Rim of Tire (V2)

The pulley wheel with the tire rim solution includes a bicycle, a trainer stand, front wheel holder, a belt, a generator, and a battery. The entire bike is made stationary and slightly lifted with the trainer stand. A front wheel holder is put in place to increase the stability of the system. The rear bicycle tire is removed so that a belt can be wrapped around the frame of the wheel providing a good fit. The belt attaches to a generator connected to the rear of the trainer. The belt ideally is taught and without slack when attached between the wheel and the generator, allowing for the most efficient generation of electricity. When someone is using the bicycle, electricity moves from the generator to an electrical system, and then to a battery that is charged by the system. This system can be adapted for use with any bike by adjusting the belt size and removing the rear tire of any bike. This allows kids and adults to use the system with a few modifications. This design will include safety features such as conduit to hide and protect external wiring and an electrical box to house exposed circuitry and the battery. This electrical box is positioned near the generator to reduce the need for extra wiring.

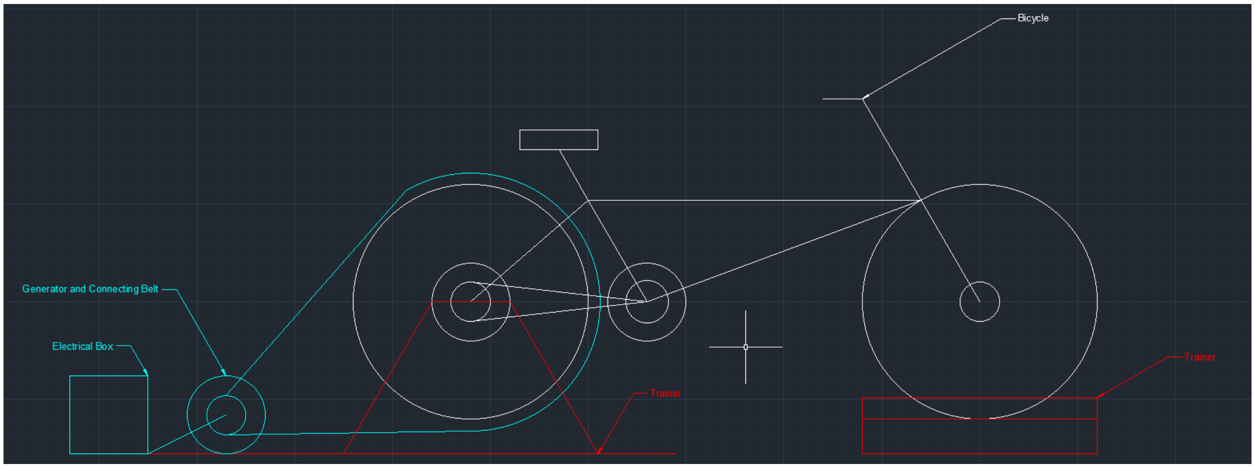

Figure 3-3 Model of V2 Pulley Wheel w/Rim of Tire

3.3.3 Low-Power Friction Mount (V3)

The Low-Power Friction Mount version involves mounting the system directly to the bike and having a rear-mounted wheel pressed against the rear tire that turns a generator. The generator runs through electronic regulators such as the battery management system and then to a small cell of batteries. The bike can then be used as usual for transportation, but in doing so, will generate a small amount of power to be stored and used later. The main difference between this version and other designs is the small footprint, light weight, and reduced power bandwidth that the system can provide. This system could be used to charge small devices in event of an unexpected emergency situation but is not suitable for powering more energy-intensive appliances. For this reason, the system can be made more lightweight with a comparatively small occupying volume due to the less powerful electronics used, allowing for excellent portability and adaptability to various bikes.

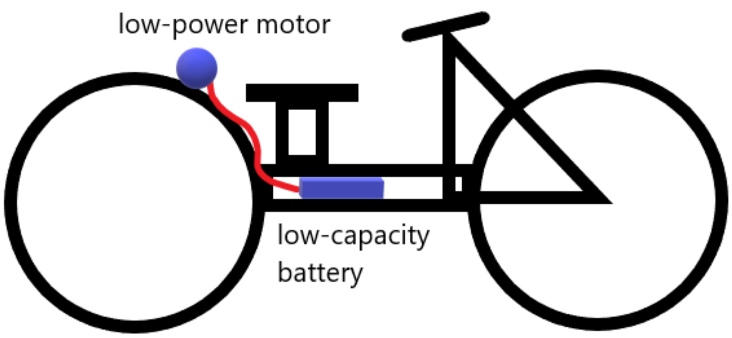

Figure 3-4 Model of V3 Low-Power Generator

3.3.4 Bike on Adapted Rollers (V4)

The Bike on Adapted Rollers is a frame built entirely separate of the bicycle and requires no modification to the bike itself. The solution involves building/modifying a stationary bike roller system by including an addition pulley that provides the input of mechanical energy into the alternator. This system would be adaptable to virtually any bicycle and would be relatively easy to set up and transport due to the simplicity of the design. This alternative solution has 4 parts: the rollers, a bicycle, an alternator, a voltage regulator, and the battery. One major drawback of this alternative solution is the high learning curve to be able to ride the machine because the rider must be able to ride completely straight for extended amounts of time.

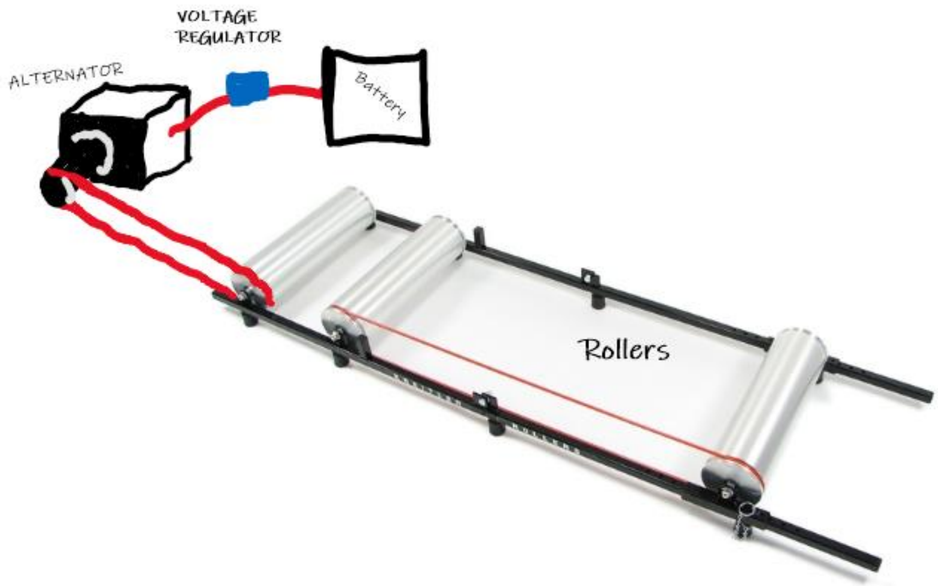

Figure 3-4 Simple Model of V4 Bike on Adapted Rollers

3.3.5 Perpendicular Dual Wheel Mount (V5)

The Perpendicular Dual Wheel Mount variant uses two wheels that are mounted perpendicular to the back tire, as shown in figure 3-6. These wheels would be able to be tightened down by an Allen wrench adjustable hex screw, and the mounting mechanism would be attached using a quick release skewer attached to the chassis directly underneath the seat. Each wheel would be its own electric generator, and a wire would be fed along the support mechanism for the wheels, and on the chassis/body of the bike towards the inner body mounted battery. The battery would be mounted by adjustable quick release skewers and a hex crew.

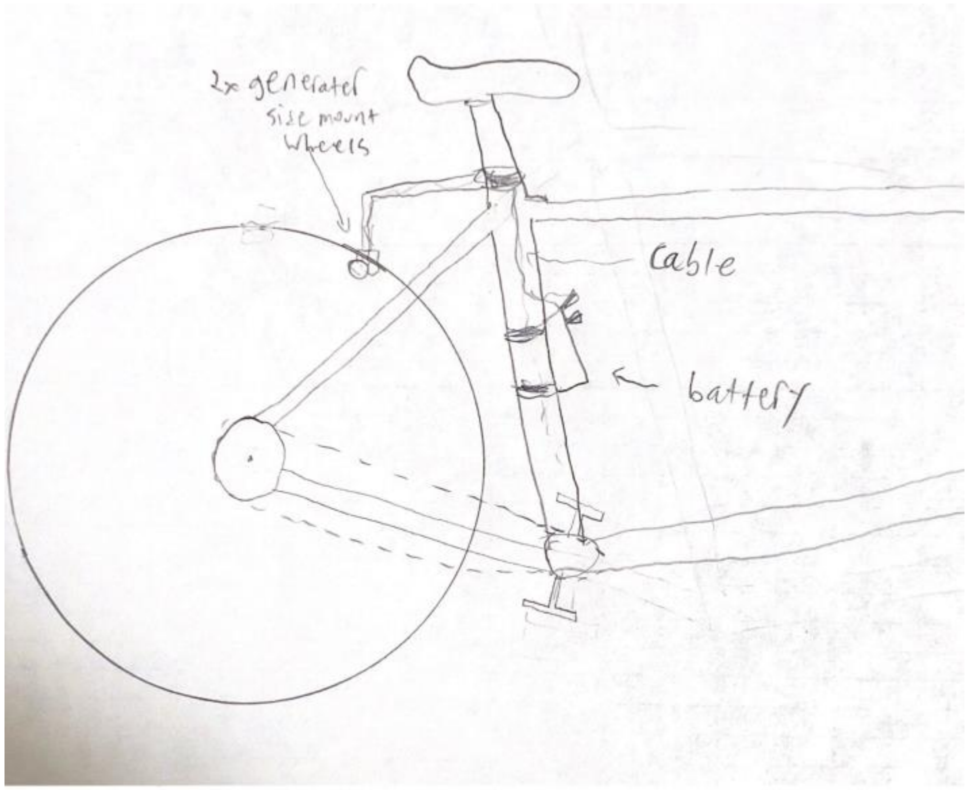

Figure 3-5 Simple Model of V5 Perpendicular Dual Wheel Mount

3.3.6 Recumbent Exercise Bike (V6)

The Recumbent Exercise Bike uses an immobile resistive exercise bike wheel in which the user sits in a chair and pedals the bike, turning a motor and generating electricity. The original resistance mechanism in the exercise bike will be replaced by the resistance provided by the motor when an electrical load is put on the system, so the bike still functions as an exercise bike. The user rotates the wheel by pedaling, which turns a pulley belt attached to the motor. The pulley wheel on the exercise bike wheel has more teeth than the pulley wheel attached to the motor, spinning the motor at a higher RPM than the user is pedaling, which helps to increase the voltage output from the motor. The electricity generated from the motor can then be used to power direct-current (DC) devices if the user maintains a consistent RPM, power an inverter to adapt the system to AC devices, or charge a battery bank that can then be used for either of the aforementioned applications.

3.3.7 Adapted Stationary Bike (V7)

The Adapted Stationary Bike includes a stationary exercise bike, a belt, a generator, and a battery. This system is similar to the bicycle pedal power generator in the way it is set up to generate electricity with the key difference being the adaptability of the system. Unlike the other system, this one is not built to work with any bike. This system is also difficult to transport due to weight and ability to remove components. An exercise bike consists of a pedaling system and one wheel. This wheel is modified to support a belt that is wrapped around the wheel. The belt is pulled fairly tight and attached to the generator system which is located close to the wheel. This system includes the generator itself, electrical circuitry, and the battery. This design keeps the electronical components hidden and works as a circuitry box which also increases user safety. When someone is using the exercise bike, electricity moves from the generator to an electrical system, and then to a battery that is charged by the system. This system is less friendly to be used by kids because it is still a piece of exercising equipment which requires more awareness to use safely.

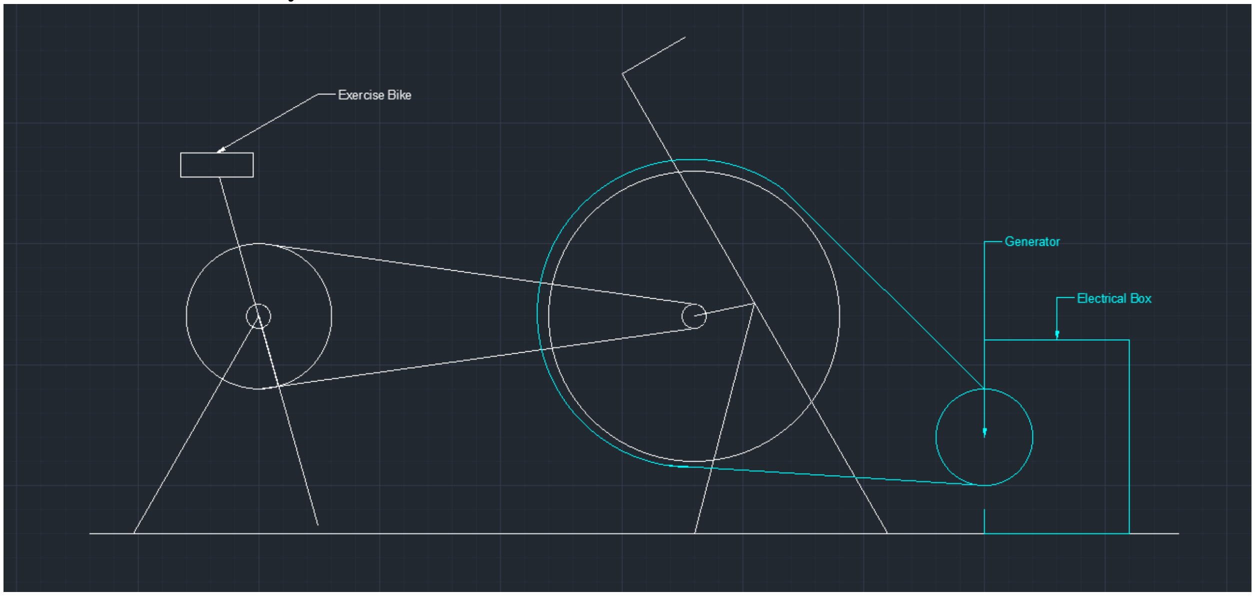

Figure 3-6 Model of V7 Adapted Stationary Bike

3.3.8 Sprocket Mounted Gear (V8)

The Sprocket Mounted Gear incorporates the use of a sprocket attached chain node that connects to a generator. This generator is located in the middle portion of the bike chassis. This would be utilized to work around the possibility of someone having a mudguard on their bike, or a seat that doesn't allow a connection on its stand. The Sprocket attachment would be a rigid connection, with a moving gear on it for the chain attachment. The chain would be fed around this gear and onto the gear of the generator in turn. The way to connect this to a bike would be done using an Allen wrench, this for ease of use of installation, as well as deinstallation. The battery and the electric generator would be attached using a quick release skewer.

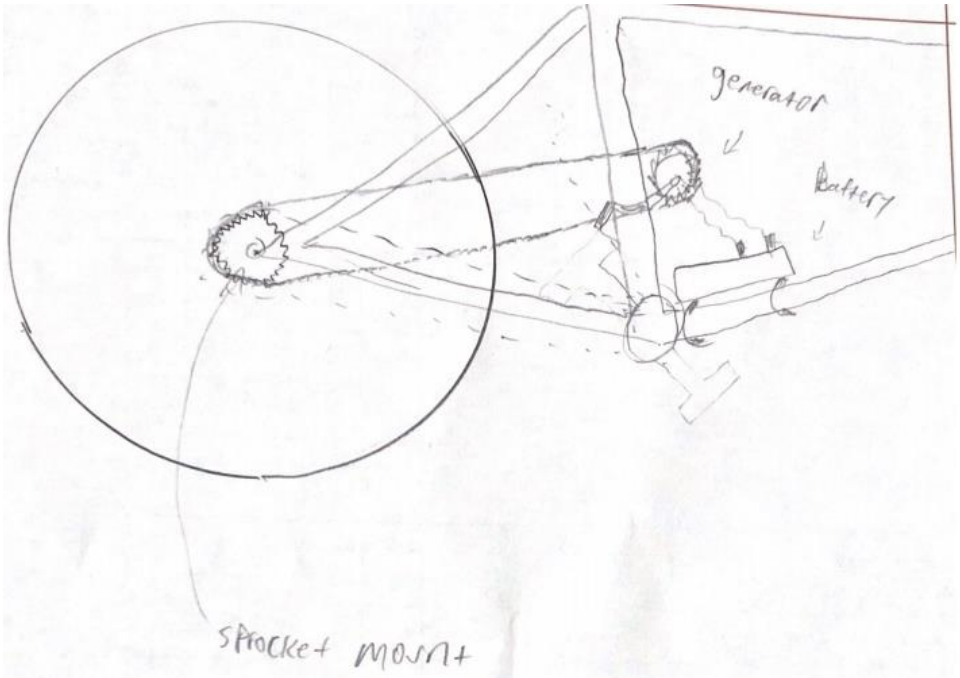

Figure 3-7 Simple Model of V8 Sprocket Mounted Gear

4 Decision Phase

4.1 Introduction

Section 4 describes and reviews the decision process for the final design of Team Techne's bicycle generator based on the alternative solutions in the section above and the criteria outlined below. The decision process took advantage of a Delphi Matrix with weighted criteria which ultimately resulted in our final decision.

4.2 Criteria Definition

The following definitions of the criteria were used in the decision process:

4.2.1 Power

The maximum amount of power that can be put out by the rider. The bike must be able to output at least 100 Watts while being operated.

4.2.2 Aesthetics

This criterion regards the amount of beautification put into the final design of the project. The final project must have the electrical components stored away and display a logo on the exterior of the module.

4.2.3 Transportability

This criterion was established to ensure the relative ease of transportability of the generator, bike, and battery.

4.2.4 Cost

Cost covers the total cost of the project and well as the possible prototypes designed in order to reach the final project. The cost will not exceed the budget laid out for us by the client combined with our own contributions.

4.2.5 Sustainability

Sustainability refers to the environmental cost of the materials and labor put into the project depending on possible waste disposal, materials used, and where the material was sourced. The goal is to produce a final project with half recycled material.

4.2.6 User Friendliness

User friendliness refers to the ease of use by the operator in terms of assembly, repairs, and while the devices is actively being used.

4.2.7 Safety

The criteria for safety are defined as a minimalized chance of injury caused by use of the machine, including risk of electrical shock or injury from the chain or the gears.

4.2.8 Adaptability

The criteria of adaptability are to create a system that will fit virtually all bikes with ease.

4.3 Solutions

- Attachable Friction Motor (V1)
- Pulley Wheel w/ Rim of Tire (V2)
- Low-Power Friction Mount (V3)
- Bike on Adapted Rollers (V4)
- Perpendicular Dual Wheel Mount (V5)
- Recumbent Exercise Bike (V6)
- Adapted Stationary Bike (V7)
- Sprocket Mounted Gear (V8)

4.4 Decision Process

The final decision of V1 was decided after much consideration. After this initial main idea, a few variations where highly considered. The second considered version was V5, as it would avoid mudguards and provide more accessibility. The next highly considered version was V2 due to it being the most similar to the second of the prototype designs provided by the client. Another consideration was the Delphi matrix in which V1 scored the highest value.

4.4.1 Delphi Matrix

Alternative Solutions Delphi Matrix (1-20)									
Criteria		Solutions							
List	Weight	Attachable Friction Motor (V1)	Pulley Wheel w/ Rim of Tire (V2)	Low-Power Friction Mount (V3)	Bike on Adapted Rollers (V4)	Perpendicular Dual Wheel Mount (V5)	Recumbent Exercise Bike (V6)	Adapted Stationary Bike (V7)	Sprocket Mounted Gear (V8)
Power	6	16 / 96	18 / 108	5 / 30	18 / 108	16 / 96	18 / 108	18 / 108	10 / 60
Aesthetics	4	18 / 72	12 / 48	16 / 64	15 / 60	17 / 68	12 / 48	12 / 48	11 / 44
Transportability	7	20 / 140	6 / 42	20 / 140	13 / 91	20 / 140	8 / 56	8 / 56	20 / 140
Cost	3	16 / 48	14 / 42	15 / 45	12 / 36	14 / 42	14 / 42	14 / 42	14 / 42
Sustainability	5	15 / 75	16 / 80	17 / 85	7 / 35	15 / 75	16 / 80	16 / 80	15 / 75
User Friendliness	9	19 / 171	15 / 135	18 / 162	3 / 27	18 / 162	18 / 162	19 / 171	14 / 126
Safety	9	20 / 180	15 / 135	20 / 180	3 / 27	20 / 180	18 / 162	18 / 162	9 / 81
Adaptability	7	16 / 112	16 / 112	18 / 126	20 / 140	17 / 119	20 / 140	20 / 140	10 / 70
Totals		894	702	832	524	882	798	807	638

Figure 4-1 Delphi Matrix

4.5 Final Decision Justification

We chose V1 as it proved to be the most efficient way to implement this sort of accessible electrical generation bike modification. Having the generator anywhere else on the bike would have been either too tight of a space, or too expensive for our budget to implement. V1 gives us ample amount of space with, solid anchor nodes nearby in the most efficient way. This by being behind the seat and above the rear gear box, usable as anchor nodes, and the generator being situated above the wheel for the space.

5 Specification of Solution

5.1 Introduction

This section reviews the final stage of the project. It goes over the physical prototyping process and how this final design came to be. The following will include the total costs, various prototypes, results, and directions and instructions on its safe use.

5.2 Solution Description

The solution has two main components: the motor and the battery. The motor was salvaged from a drill and makes use of a gear box to produce a valid wattage. This motor is spun by attaching its frame via the seat post of a bike and spinning a skateboard wheel using friction with the back tire. The motor is connected to the battery through a DC-DC voltage regulator, which allows for variable inputs of voltage depending on the speed of the motor and into the DC input port. When the bike is ridden, the skateboard wheel turns the gearbox which then turns the motor. The motor provides power to the battery which is stored and can be used later.

5.2.1 Gear System

The gear system was designed after noticing that the power output of the motor was only 1.6 watts without anything. The gear was designed on Fusion360 as a 6:1 ratio to produce more wattage then 3D printed and fitted with the motor on the seat post frame.

5.2.2 Motor

The motor was salvaged from a dismantled drill bought from a Goodwill secondhand. It is a brushed DC motor and has a diameter of 46 millimeters and a length of 90 millimeters and has a 16-tooth gear on the end with an 11.5 millimeter diameter.

5.2.3 Battery

The battery being used for the project is a Nusgear portable rechargeable battery bought off Amazon for $100. It has a capacity of 167 watt-hours, can output 100 watts, has an inverter onboard for AC plugs, and can output on 4 USB ports and 2 DC outputs.It has a capacity of 167 watt-hours, can output 100 watts, has an inverter onboard for AC plugs, and can output using 4 USB ports and 2 DC outputs.

Figure 5-1 Nusgear battery and I/O ports

5.2.4 Electrical Components

The motor is connected to the battery through a DC-DC voltage regulator, which allows for variation of voltage which is proportional to the speed of the motor. The regulator outputs a constant voltage compatible with the battery's charging system and charges the battery through the DC input port below the flashlight module.

5.2.5 Mount

The mount was designed up in AutoCAD then transferred onto Fusion360 so that it could be 3D printed with ABS filament. The frame was designed with 2 parts that can be adjusted to fix different bike tire sizes. The first component stores the motor, gearbox, wheel, and the electrical guts. The second component attached to the first at adjustable angles and is attached via the seat post.

5.3 Cost Analysis

Cost analysis outlines the design, implementation, and maintenance costs for the project.

5.3.1 Design Cost

The time spent was divided into 3 sections: Research and Organization, Prototyping, and Constructing the Final Design. The total hours for these sections were, respectively: 80 hours, 50 hours, and 20 hours. This ended up being a total of 150 man-hours total for the team.

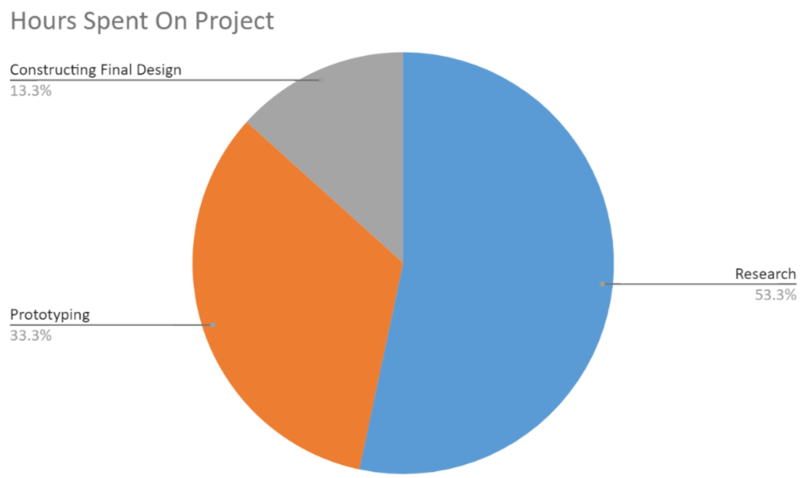

Figure 5-2 Pie Chart of Hours Spent

5.3.2 Implementation Cost

PART NAME	COST (USD)
Skateboard wheel(s)	$8.00
Skateboard bearings	$9.00
DC-DC Voltage Regulator	$4.50
3.5x1.35mm DC jack	$7.00
Heat shrink tubing	$5.89
ABS filament	$23.00
Nusgear Survival Battery	$107.24
Drill Motor	$6.00
Assorted hardware	$5.70
Total cost	$176.33

Figure 5-3 Total Costs of Materials

5.3.3 Maintenance Cost

The estimated costs for each year are around $25 for wheel bearings and various worn-out plastic parts each year. A full replacement of the battery and motor would be necessary every 3-5 years of frequent use which would cost around $145 dollars.

5.4 Prototyping

Included below are photos of prototyping for the final design. Included are a drawing drafted in Auto CAD of the seat post frame, initial modeling of the motor and the bike wheel, and a model of the gear system, motor, and attached skateboard wheel rendered in Fusion360.

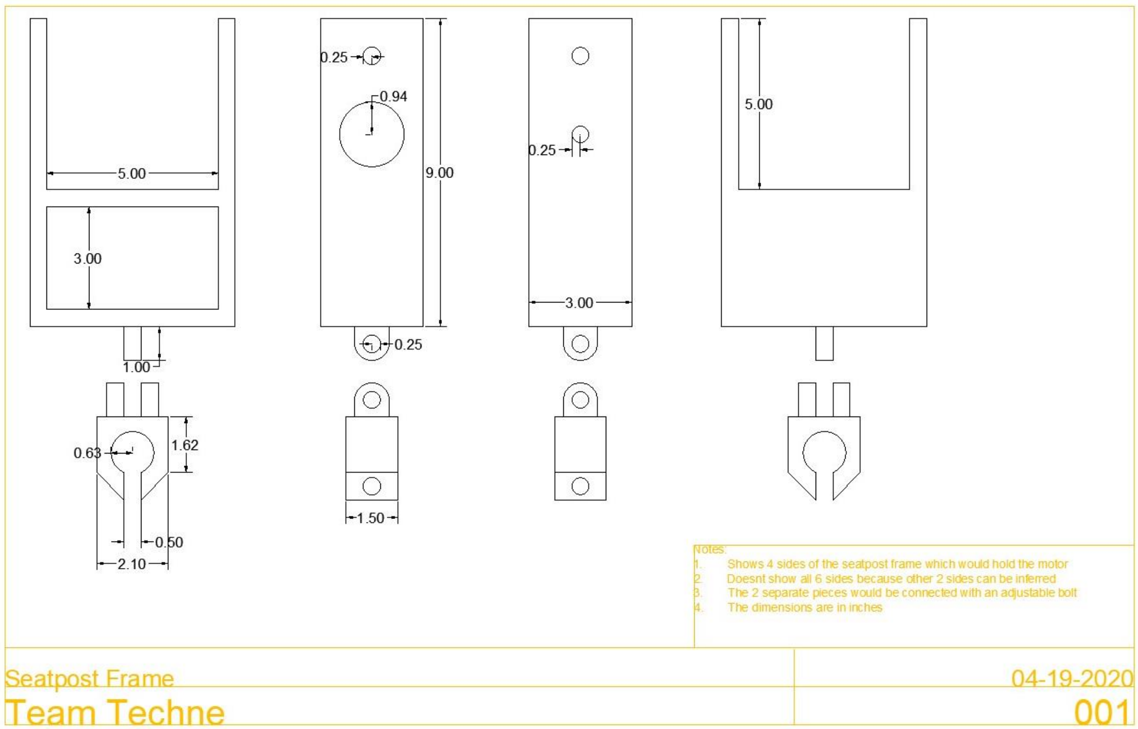

Figure 5-4 AutoCAD drawing of the Seatpost Frame

Figure 5-5 Initial modeling of the motor and bike wheel

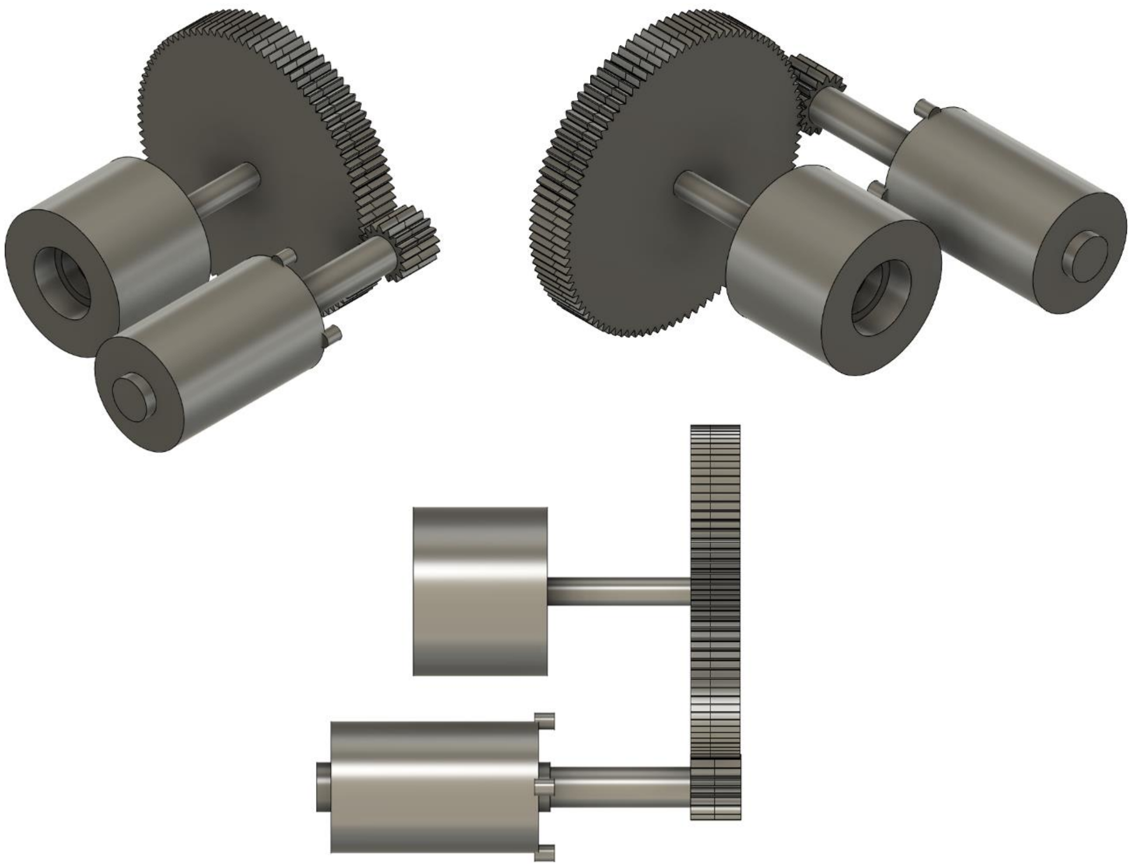

Figure 5-6 Renderings of the gear system, wheel and motor

5.5 Instructions for Implementation and Use

5.5.1 Printing

5.5.1.1 Materials:

ABS

ABS-compatible 3D printer

Superglue

Slicing software

5.5.1.2 Procedures:

Download all relevant STL files.

Slice the files into GCODE with the slicing software of your choice.

Print resolution should be 0.3mm layer height or better; all models printed here used a 0.2mm height.

Transfer GCODE file to 3D printer or printer control software and begin print. Use appropriate temperature(s) on extruder and hotbed according to filament specifications.

Print files according to table below:

Part name	Quantity	Infill percentage
Shaft 1	1	100
Shaft 2	1	100
Shaft 3	2	100
Wheel bearing a	2	100
Post clamp	1	50
Bearing holder	3	100
Motor housing	1	100
Motor spacer	1	100

Figure 5-7 Table describing infill % and quantity

Assemble pieces according to 3D model using a strong plastic-binding adhesive, such as superglue.

5.5.2 Frame assembly

5.5.2.1 Materials:

¼" thick plywood sheet

Superglue

Nail gun and wood-compatible adhesive

5.5.2.2 Procedures:

Cut the pieces according to table below:

Part name	Quantity	Length (mm)	Width (mm)
Side walls	2	175	75
Inside wall	1	154	75
Rear wall	1	168	75
Floor	1	154	52

Figure 5-8 describes quantity and dimensions of frame walls

Drill a ½" (diameter) hole in the left side of the inner wall.

Assemble the box according to the 3D model with glue and nails, then let dry. The glue will generally take ~24 hours to dry, but the structural rigidity should be immediate due to the nails.

When assembled, the frame should look like this:

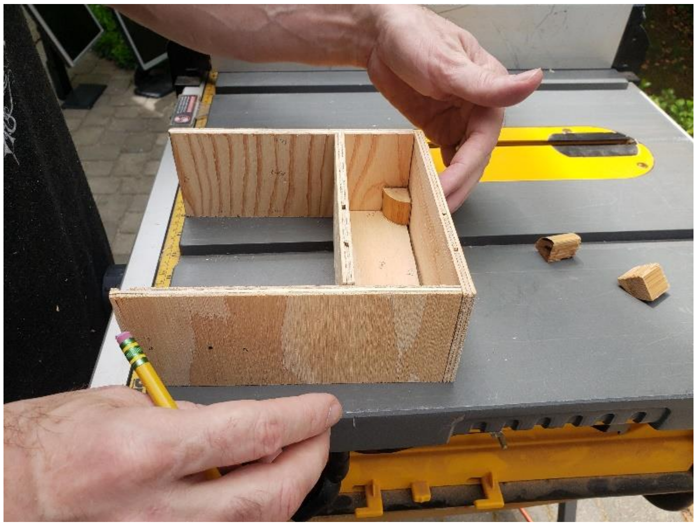

Figure 5-8 Picture of wooden frame being built

5.5.3 Electronics assembly

5.5.3.1 Materials:

Heatshrink tubing, heat source (lighter)

Soldering iron, solder

Wire

DC jacks

Voltage regulator

Motor

5.5.3.2 Procedures:

Slide a heatshrink tube onto each end of the extension wire.

Twist the **positive** wire of the motor onto the **negative** end of the extension wire and vice versa; the polarity swap is due to the direction the motor is spinning creating a negative voltage.

Solder the wires together.

Slide the heatshrink tube over the exposed wire and apply heat to insulate the connections.

If you have not completed 'components assembly' yet, revisit this step later.

Thread the extension wire through the hole in the motor mount component/inner wall and slot the motor in.

Carefully solder the extension wires to the input of the voltage regulator.

Solder another length of wire to the output terminals of the regulator and secure the regulator to the frame with an adhesive.

As the portable power supply that is used has a **center-positive** DC input, the center contact of the DC jack needs to be soldered to the positive end of the wire. Slide back the plastic sheathing on the DC jack and carefully solder positive to the center and negative to the outer contact.

Replace the plastic sheathing over the contacts.

5.5.4 Components assembly

5.5.4.1 Materials:

3D-printed parts

Superglue and/or wood-compatible adhesive

Frame

Skateboard wheel

Motor

Bearings

Voltage regulator

Wire

1.3mm x 3.5mm DC jacks

Soldering iron, solder

Hardware

5.5.4.2 Procedures:

All parts printed have a small size difference between the shafts and their appropriate sockets as a tolerance factor for inconsistent sizes of pieces from 3D printing.

Glue 3D-printed components together according to the 3D model; make sure when gluing a shaft to an adapter or a gear to set the shaft completely perpendicular to the component you are attaching it to.

Insert the wheel bearing adapters into the skateboard wheel and glue them together using a plastic-compatible adhesive; superglue or Gorilla glue is appropriate. Assemble other components attached to skateboard wheel.

Glue the bike seat post clamp's hinge to the outer rear wall of the frame.

Let glue dry for at least 1 hour.

Glue bearing holders, motor mount and motor spacer onto plywood sides according to this diagram:

Complete the electronics assembly before proceeding.

After electronics assembly is complete, slide the 16-tooth motor gear adapter on the motor gear. Place a bearing in the adjacent bearing holder and carefully put the axle in the bearing. The plywood is flexible enough to allow bending if necessary.

Insert another bearing into the front-left bearing holder and insert the assembled components (skateboard wheel, 96-tooth gear, axles). Put another bearing in the right-side bearing holder and carefully put the axle in the bearing. The two main gears should now be touching and should rotate one another.

Insert the bolt into the rear hinge and secure the nut to the other end. Tighten and adjust as necessary to maintain a good connecting friction between the skateboard wheel and bike tire.

Clamp the frame around a bike seat post and insert the screw into the clamp, securing it into the nut. Tighten screw as needed if clamp is too loose.

5.6 Results

As seen in 5-9, the final product is a 3D model in Fusion 360. The design incorporates a brushed DC motor from a power drill, a 60mm polyurethane skateboard wheel, 3D-printed axles, housing, and 6:1 gear system, a DC-DC voltage regulator, and a battery-powered portable power supply, along with assorted hardware, adhesives and wiring. These printable parts allow the user to create the system from a collection of STL files.

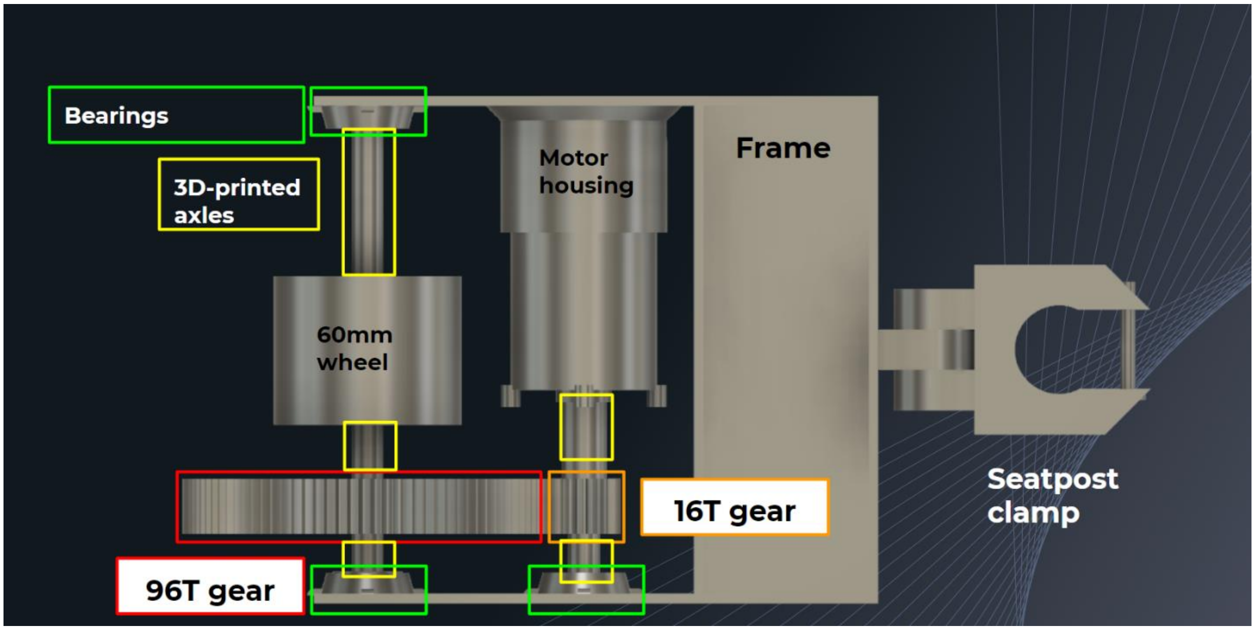

Figure 5-9 Renderings of all components in their respective final places

6 Appendices:

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