Grassroots EV Motorcycle Kit

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ABSTRACT

The initial concept for this project originated from searching for an affordable and small electric vehicle to use while moving about campus. This would allow students to transport themselves to class everyday in an ecofriendly manner in addition to reducing full size vehicle traffic around campus. After some research, a clear lack of budget EV transportation of this type became apparent. In order to keep the cost down, the project quickly became how can older vehicle platforms transform into viable electric transportation. After acquiring a 1973 Yamaha TX500 for $250, the project continued into the design stage.

In order to properly develop the necessary components, the bike was recreated in SolidWorks using a custom grid system made of string. After the bike frame was virtually created, virtual representations were made of each needed custom component to help develop the best possible design regarding cost, strength, and longevity. SolidWorks also allows for simulations of each component according to the forces acting upon them during use. This will ensure each component design is able to withstand operational forces present within the system. With the design work finished, the project moved into manufacturing and testing.

The project manufacturing took about fifty days to complete from start to finish. Most of the project work comprised of ensuring proper dimensions for fitment on the bike and the system wiring. A few of the most utilized tools used include various metal cutting wheels, a 10-inch drill press, and various electrical tools such as large crimping pliers and wire strippers. The testing comprised of four different parameters judged against the qualities of the original bike platform and/or mathematically derived metrics. These parameters include range, acceleration, braking, and maneuverability. Ultimately, the bike improved in two of the parameters, saw no change in another, and failed to meet a single parameter.

PROBLEM DEFINITION AND RESEARCH

PROBLEM STATEMENT

The age of renewable resources brought forth a vast sea of vehicles combating traditional fossil fuel transportation. However, many of these vehicles are monetarily unobtainable for younger generations or simply too large and impractical for the urban centers younger generations tend to live within. Additionally, many modern electric vehicles rely upon newly manufactured parts that are often taxing on various resources present in our environment.

RESEARCH

BACKGROUND AND SCOPE OF THE PROBLEM

The average American citizen relies heavily on personal vehicles to travel within the United States. Although public transportation does exist within some urban epicenters, many cities in the United States have underdeveloped systems, specifically compared to our European colleagues. Additionally, personal vehicles will always provide greater convenience and adaptability in the United States, only about 5% of commuting adults use public transportation daily. The Statistics reported by the Bureau of Transportation Statistics (BTS)— the principle Federal statistical agency at the U.S. Department of Transportation, show that American Citizens spent 1,176 billion dollars on personal vehicle expenditures in 2015. This is approximately 9.2% of all personal consumption expenses for the year 2015. Additionally, all forms of transportation expenses/investments made up 9% of all GDP for the United States. This clearly displays the vast resources put into various transportation forms by the United States every year. Moreover, it displays the intense effect of fossil fuels on our world environment. In total, roughly 71% of all petroleum use in the United States applied to transportation in 2015. This equates to roughly 27% of greenhouse gas emissions for the same year.

Although personal vehicle transportation in the United States provides convenience and affordable means of travel for the average citizen, ultimately fossil fuel powered vehicles are taxing on our economy and environment. The increasing use of personal vehicles by Americans, currently at around 204 million vehicles within our borders, also puts a strain on our infrastructure and ease of travel. The US Department of Transportation reports that traffic congestion delays in the United States went from 5.6 billion hours in 2002 to 6.7 billion hours in 2012. This excludes delays caused by poor infrastructure resulting from a continuous increase in vehicle traffic. This data applies to the entirety of the United States, in order to better develop a solution to urban traffic congestion and pollution, the University of Cincinnati provides an appropriate testing ground.

The University of Cincinnati resides in an urban environment congested by traffic and human flow. The University and some private companies have attempted to provide transportation solutions for the average student. Companies such as Uber and Bird provide transportation but are ultimately unpredictable and at times quite expensive. Additionally, Uber further congests traffic around campus. The average student living off campus at UC rarely ventures outside the bounds of Clifton for basic life necessities, an example being groceries. A small vehicle with a limited range but also with low initial and operating costs could relieve traffic and save students stress and money. Many old motorcycle chassis provide ample space for an electric conversion and cost next to nothing to obtain due to previously large production numbers. This would allow a company to produce an EV conversion kit for the younger generation compatible with many older motorcycle models cheaper than traditional transportation while appealing to an energy saving generation.

CURRENT STATE OF THE ART

Many companies have appeared in the last few years ready to offer an electric motorcycle to American consumers. The most advanced form of battery technology as of currently is the lithium-ion cell, which currently seems to dominate the market. Lithium-ion batteries provide better performance in almost every category compared to traditional lead acid batteries except for cost.

Many of the companies providing electric motorcycle transportation utilize this battery, making their product a better performer while sacrificing an affordable price point. Although research suggests that lithium-ion technology will decrease severely in price over the next 10 years, currently the price point remains out of reach for young Americans wanting affordable, clean transportation. A few 2019 models reflect this conclusion:

2019 Harley-Davidson LiveWire

This brand-new entry for Harley-Davidson utilizes the lithium-ion cells described above. The current system offers about 146 miles of range. The bike allows recharging from any home outlet or EV station throughout the United States. Additionally, this bike also utilizes defensive riding technology, allowing inexperienced riders to successfully ride in traffic and urban conditions. The base price of the LiveWire starts at $29,799.

Tarform Electric Motorcycle

The Tarform Electric Motorcycle is based upon a modular system allowing for greater customization by the customer. The range of the standard model is approximately 90 miles with just under 4 hours for a full recharge at any standard outlet. The Tarform bike bases many of its features on smart technology. An app is available to record the health of the bike and various other data recorded simply by riding the bike. This bike contains less range than the LiveWire but has a more affordable price point of $18,000.

END USER

The end user of the bike is a young American citizen residing in an urban environment. This consumer’s focus resides mostly within affordable forms of personal transportation. This consumer also will have focus driven towards ease of use and maintenance. These are two large areas that seem to lack currently with large production electric motorcycles. An urban area provides for room to reduce range without affecting usability, a large factor in calculating production costs. This target consumer will also possess minimal mechanical skills, another reason to simplify the construction process.

CONCLUSIONS AND SUMMARY OF RESEARCH

Ultimately, the current electric motorcycle market offers many different brands and models over the $15,000 price point. However, the market under this price point fails to offer an affordable motorcycle to consumers. The market also fails to offer a kit to convert already existing motorcycle components into a fully functional electric form of transportation. It is with this route that a new market can be exposed, fundamentally changing the way we travel in urban centers.

QUALITY FUNCTION DEPLOYMENT

CUSTOMER FEATURES

Senior Design Survey Results (30 people surveyed)

Concern for the environment	1(0%) 2(0%) 3(6.7%) 4(53.3%) 5(40%)
Ease of transportation	1(0%) 2(0%) 3(16.7%) 4(46.7%) 5(36.7%)
Comfort of transportation	1(0%) 2(10%) 3(33.3%) 4(40%) 5(16.7%)
Compactness of transportation	1(0%) 2(36.7%) 3(30%) 4(33.3%) 5(0%)
Ease of transportation use	1(0%) 2(0%) 3(40%) 4(53.3%) 5(6.7%)
Safety of transportation	1(0%) 2(0%) 3(0%) 4(70%) 5(30%)
Efficiency of transportation	1(0%) 2(0%) 3(6.7%) 4(36.7%) 5(56.7%)
Appearance of transportation	1(0%) 2(6.7%) 3(6.67%) 4(63.3%) 5(23.3%)
Available seating for multiple people	1(0%) 2(0%) 3(10%) 4(46.7%) 5(43.3%)

In what environment do you mostly drive?
Highway(36.7%) Urban(63.3%) Rural(0)

Do you currently have a garage at your residence?
Yes(80%) No(20%)

How often do you use transportation (Personal, Uber, Train, bike, etc.)?
Multiple times a day(36.6%) Once a day(40%) A few times a week(23.3%) Rarely(0)

Do YOU have access to affordable PERSONAL transportation?
Yes(66.7%) No(33.3%)

Do you support the development of electric vehicles?
Yes(100%) No(0)

How much traffic do you experience in average when you drive?
Heavy(43.3%) Medium(56.7%) Low(0)

There seems to be a high emphasis on reducing carbon footprint and developing clean vehicles. Although people seem to not care about the overall size of their transportation. People also seem to care about the look of the transportation they use. The multiple seats problem cannot be fixed but a motorcycle could certainly fit many of these categories. Many people report mainly urban transportation use in somewhat heavy traffic. Also, many college aged adults report they cannot afford a traditional car on their own.

ENGINEERING CHARACTERISTICS

The motorcycle will address customer features by continuing on the current trajectory of creating environmentally conscious transportation for an affordable price. Efforts will be made to increase the usability and quality of the bike whenever possible. The desire for compact transportation that is valuable in heavy traffic fits the profile of a motorcycles purpose. The rideability will be tuned to better accept usage in urban areas.

HOUSE OF QUALITY

				Direction of Improvement: Minimize (▼), Maximize (▲), or Target (x)	X	▲	▲	▲	▼	▲	▲
Row #	Max Relationship Value in Row	Relative Weight	Weight / Importance	Quality Characteristics (a.k.a. "Functional Requirements" or "Hows") / Demanded Quality (a.k.a. "Customer Requirements" or "Whats")	Efficiency	Ease of Use	Comfort During Use	Safety of Transportation	Overall Size and Weight of Transportation (Compactness)	Appearance of Transportation	Additional Rider Capacity
1	9	20.0	5.0	Range	Θ	▲	O	▲	Θ	▲	Θ
2	9	12.0	3.0	Speed	Θ	O	O	Θ	Θ	▲	O
3	9	16.0	4.0	Indicator Lights (Safety)	▲	Θ	Θ	Θ	▲	O	▲
4	9	16.0	4.0	Attractive Appearance	▲	▲	O	▲	▲	Θ	▲
5	9	8.0	2.0	Display Hud Unit	▲	Θ	O	O	▲	Θ	▲
6	9	16.0	4.0	Simplified Layout	O	Θ	▲	▲	O	O	▲
7	9	12.0	3.0	Larger Seat (Luggage, etc.)	▲	O	Θ	▲	O	O	Θ
8											
9											
10											
				Target or Limit Value							
				Difficulty (0=Easy to Accomplish, 10=Extremely Difficult)	9	2	3	4	8	5	1
				Max Relationship Value in Column	9	9	9	9	9	9	9
				Weight / Importance	388.0	468.0	436.0	340.0	412.0	380.0	380.0
				Relative Weight	13.8	16.7	15.5	12.1	14.7	13.6	13.6

Figure 1

PRODUCT OBJECTIVES

The Product objectives are as follows:

- Capitalize on the lack of budget EV transportation
- Capitalize on forgotten components left to rot away
- Capitalize on less relevant but still effective technology
- Capitalize on cheaper technology and methods
- Make a product that easy for the customer to assemble and operate
- Make a product customers will be comfortable operating

The end product goal is a kit that utilizes the old componentry of various forgotten motorcycle models and the less relevant but still effective EV energy methods. Using this methodology, three kit options will be offered:

1. The first will be a “small kit” that offers an EV conversion for most bicycles. Small range but easy to assemble and very affordable.
2. The second will be a “medium kit” that offers an EV conversion for most average sized motorcycles approximately 350cc to 650cc). A range suitable for city life, somewhat easy assembly and affordable.
3. The third option is a “large kit” that offers an EV conversion for large frame motorcycles (approximately 750 cc and up). An extended range, somewhat easy to assemble and slightly less affordable than the medium kit.

The Medium Kit is the scope this project will physically complete.

This project utilizes a 1973 Yamaha TX500 motorcycle. This bike is a good representation of forgotten technology that still offers suitable transportation and is similar to other bikes of this generation that the kit is marketed towards. The project will utilize all components not related to the combustion engine.

DESIGN

The design decisions made throughout the build are to reflect a few basic principles:

1. Simplicity. The custom work designed on the bike must allow for ease of assembly (avoiding processes like welding, brazing, etc.)
2. Reuse. When possible, existing geometry present on the bike will be utilized.
3. Affordable. The parts used on the bike will be affordable parts that are easy to replace when necessary.
4. Safe. Parts used in design will be above the minimum requirements to withstand the forces present within the system.

With these design considerations now established, the creation of the project can be narrowed down to a few major steps:

1. Create virtual CAD representation of bike
2. Develop battery mounting system
3. Develop motor mount system
4. Design OR choose Sprocket system
5. Wiring Diagram

Unfortunately, 2D frame drawings do not exist or are not readily available for the TX500 model. This means the dimensions must be taken directly from the bike frame itself. With a dimensionally accurate CAD model, the rest of the project development can take place virtually.

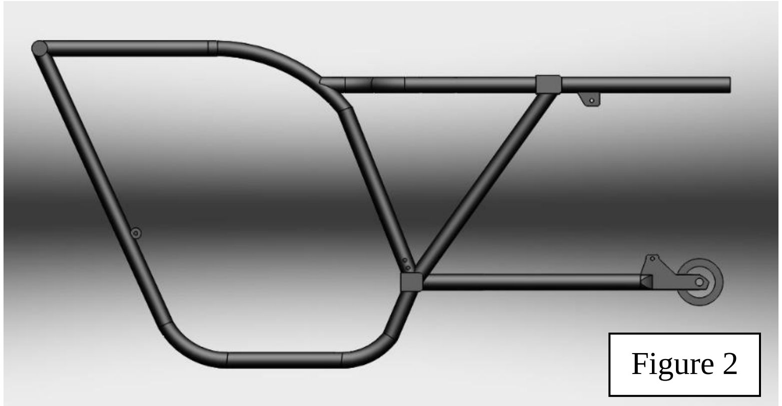


Figure 2

The battery tray design utilizes angle iron and flats to create a sturdy "tray" for the batteries to sit in. The design utilizes mounting points already present on the bike in addition to some simple drilled through-holes. The Design uses only bolts and screws and does not require any welding or other intense processes. This ensures assembly can be completed by someone with little engineering knowledge or experience. This also ensures the kit can apply to a wider range of motorcycle models, as the kit can be trimmed and adjusted to cater towards small dimensional differences between models.

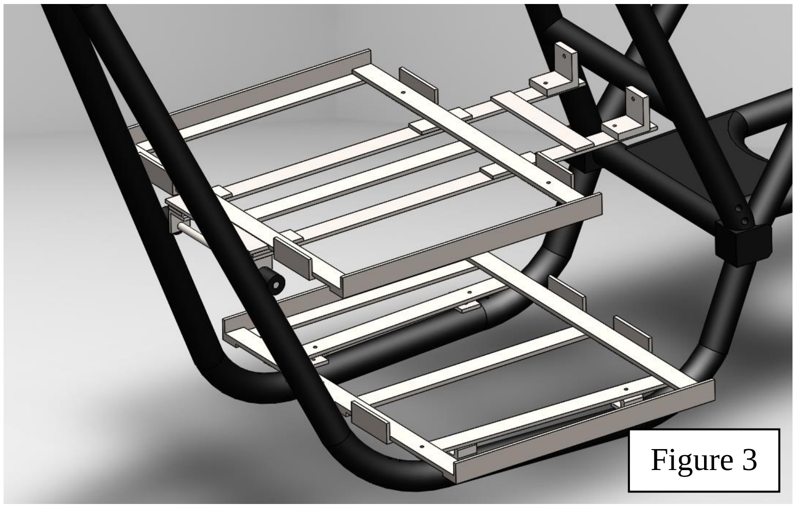


Figure 3

This project will utilize a Permanent Magnet Brushed DC electric motor rated at roughly 300-amp peak output (150-amp continuous) and 18 HP. Although 18 HP does not seem like much, electric motors provide almost all available torque/power across the RPM range; traditional combustion engines require the engine to rev up towards a high RPM to reach peak performance – electric motors provide all available power almost instantaneously. So combustion engines measure HP at peak performance, electric motors measure continuous power. Electric motors also tend to cruise at higher RPMs as well, ensuring the motor is already wound and ready to deliver power. The motor mount also utilizes carbon steel angle iron. Simple Bolt and screw construction to avoid welding and other complex methods. Must withstand the torque and power of motor (3 points of contact will be the standard). Must avoid path of the propulsion system (Chain, drive gear, etc.). Developed in a way to contain parts and protect rider if a system failure were to occur.

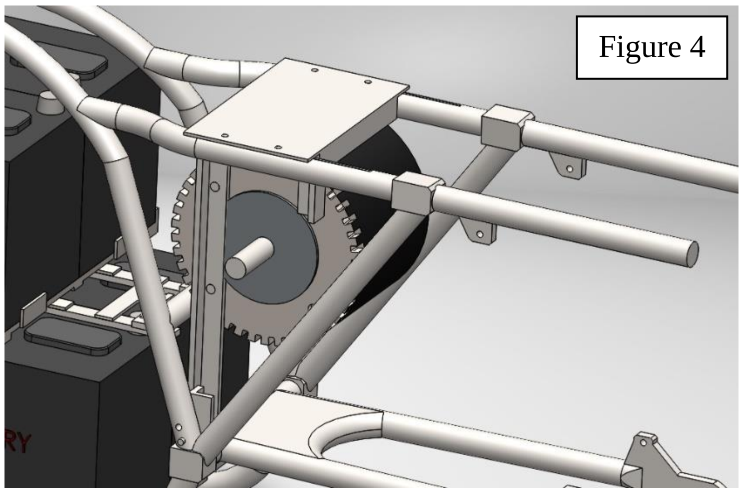


Figure 4

The original setup of this motorcycle included a transmission with 5 gears. This transmission is necessary to get the bike up to speed as the traditional combustion engine cannot create enough torque to run on a single gear. As previously discussed, this DC engine creates ample torque evenly across the powerband. Therefore, no transmission is necessary and a single gear will be used. A sprocket system that has a higher gear ratio will accelerate faster and use less initial amperage, however, top speed is lost. The drive sprocket will remain similar to the original – a small 12 to 18 tooth sprocket. The driven sprocket must increase in size – somewhere in the range of 65 to 80 teeth. The theory behind this sprocket system is creating the right ratio to suit the speed and acceleration desired by the builder. For this project the desired top speed will be approximately 50 mph.

This system is extremely simple and utilizes low-cost parts. The drive sprocket can be ordered from any industrial supplier or even most hardware stores. The Driven sprocket is ordered to my desired specifications and sent to my door all for a reasonable price. The drive gear is held in place on the driveshaft by a hub key. The drive chain is a simple #40 chain found at most hardware stores, affordable and safe. The chain is cut to length by punching out rivets at the desired length and inserting a master link to re-attach the chain. All of this is essentially the same to how a child's bicycle works.

The wiring is made up of 4-gauge weld wire, more than suitable to handle a 48V system. The system is controlled by a systems controller – a device that quickly turns power on and off to limit power distribution (same tech used for LEDs). A kill switch (On/Off) and Main fuse will be present in the system for safety and ease of use. The kill switch utilizes a spring contactor plate, when the switch is thrown the circuit is immediately broken. A DC/DC converter will be used to run auxiliaries like the lights and signals, this converter simply gets wired directly to the 48V system. This is the basic system theory, the budget has allocated funds for some additional components that are not essential to bike function if time so allows.

DESIGN ALTERNATIVES AND SELECTION

The design alternative to the purposed plan is a kit that focuses on installation through welding. Although a cleaner look, welding is a skillset most in society do not possess. Marketing a kit for welding only immediately limits the customer base most likely to purchase the kit. In fact, the targeted customer will most likely not be able to afford a welder to complete the project anyway – as the price of a welder is over half that of the entire motorcycle from start to finish. The bolt on kit ensures the system is at least equally as strong if not more, and will allow for easy installation with hand tools.

ENGINEERING CALCULATIONS

List of equations

$$\frac{Cold\ Cranking\ Amps\ (CCA)}{7.25} = Amp\ Hours$$

$$Watts = Amps * Volts$$

$$Watt\ Hours = Volts * Amp\ Hours$$

$$Estimated\ Range = \frac{Watt\ hours}{\frac{Watt\ hours}{mile}}$$

$$W = EI$$

$$\frac{W}{745.7\ W} = HP$$

$$Gear\ Ratio = \frac{Driven\ Sprocket}{Drive\ Sprocket}$$

Loading Conditions – Battery Tray and Motor Mount Simulations

Battery Tray

• Battery tray is constructed entirely of 1/16” and 1/4” thick angle iron or flats.

• Battery tray is bolted together using either 1/4” or 5/16” diameter bolts and locking nuts.
• In the simulation, the mounting tabs are used as the anchor points (2 mounts 1/4” and 2 mounts 1/8”)
• An applied load of 164 lbs. (728N) is applied along the 2 rails in direct contact with the battery for each tray (shown next slide). This is twice the expected load hence the FoS of 2.
• FoS = 2

Stress Results:

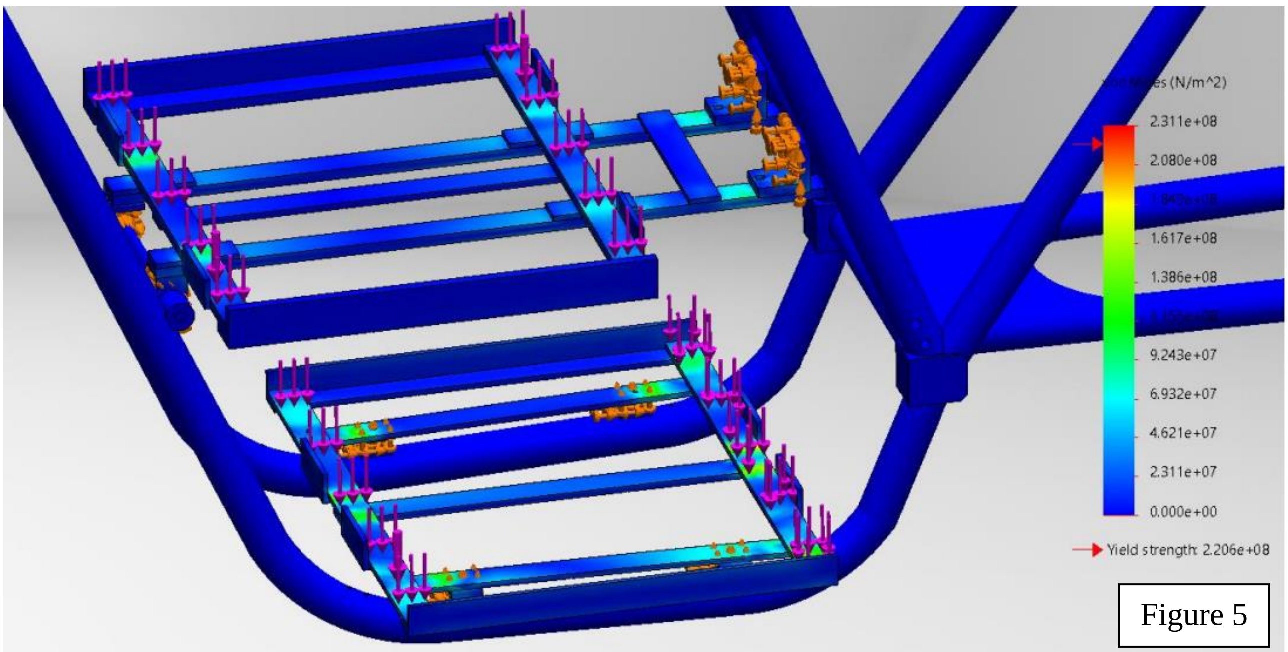


Figure 5

Motor Mount
• The motor mount construction consists entirely of 1/8” x 3/4” angle iron.
• The mount bolts to the frame with 1/4” bolts.
• The torque force applied to the simulated motor model is 32 ft-lbs (The max torque specification provided by the engine manufacturer). Simulation is done at 86 ft-lbs.
• The model representing the motor internals weighs roughly 17 lbs. (The entire motor weighs about 25 lbs.).
• The diameter of the drive shaft is 7/8”.
• The bolts attaching the motor to the mount are 3/8” bolts.
• The material used for simulation is low carbon steel A36 unless otherwise specified.
• FoS = 2

Stress Results:

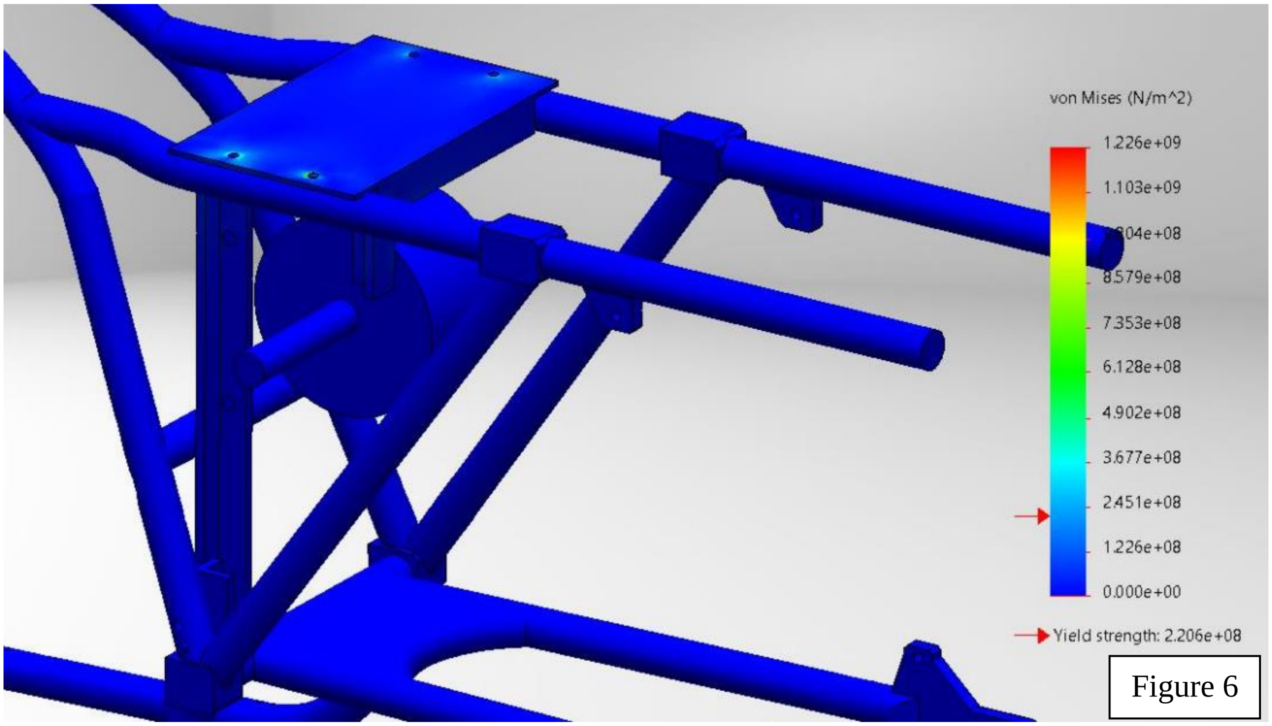


Figure 6

Material Selection

The material used to make all custom components is ASTM A36 hot rolled steel. This steel has a low carbon content by weight (less than 0.3%) and is a favorable steel for custom fabrication including drilling, cutting, and welding. This steel has a yield tensile strength of over 36,000 PSI, making it more than strong enough to handle the forces the motorcycle can generate. It is also affordable and extremely easy to obtain, making it even more attractive for a fabrication project such as this.

Motor Calculation

HP at continuous 150 Amp level:

$$W = EI$$

$$W = (48V)(150) = 7200\,W$$

$$\frac{7200W}{745.7W} = \mathbf{9.66\ \mathit{HP}}$$

HP at 350 Amp max level:

$$W = (48V)(350A) = 16800\,W$$

$$\frac{16800W}{745.7W} = \mathbf{22.53\ HP}$$

Sprocket and Range Calculation

$$Gear\ Ratio = \frac{Driven}{Drive}$$

$$GR = \frac{72}{14} = \mathbf{5.14:1}$$

After consulting a gear ratio chart, a 5.14:1 ratio returns a top speed of ~**50 MPH**.

$$48V * 75Ah = 3{,}600\ Watt\ hours$$

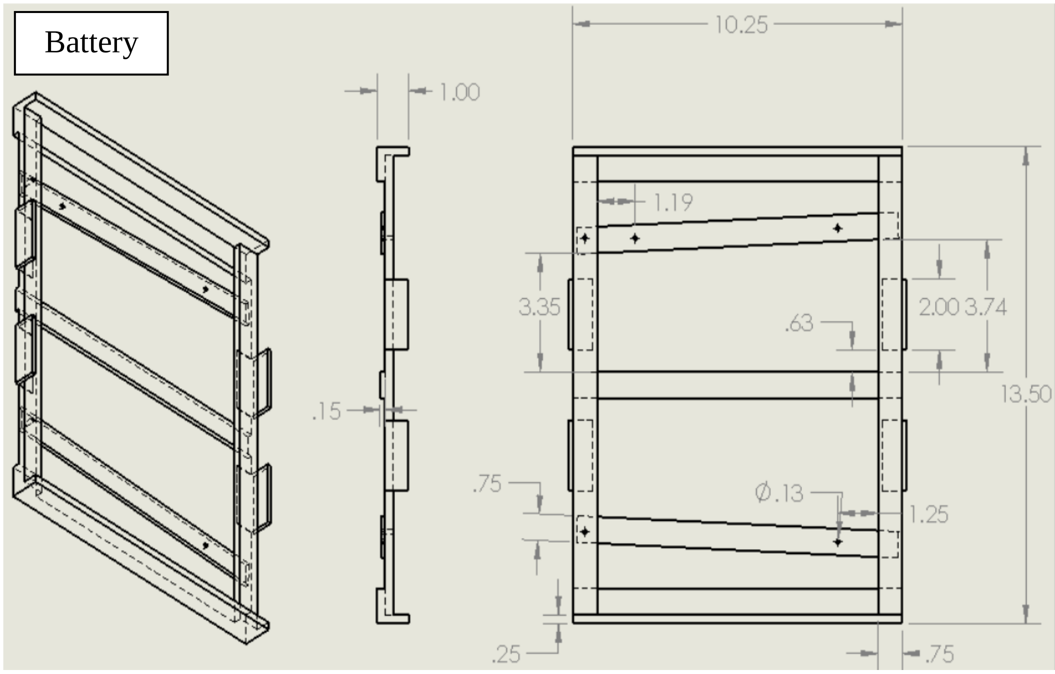
$$\frac{3{,}600\ Wh}{110\ Wh/mi} = \mathbf{\sim 32\ miles}$$

110 Wh/mi is a value obtained using a 12V car battery as a reference against a mid-size motorcycle.

Factors of Safety

In order to design a system that will properly withstand regular usage, the factor of safety I employed is 2. Therefore, each design will be built to twice the amount of force expected to be present in the system at any given time. This will ensure the designs can withstand regular usage or the occasional outlier force exercised on the system.

MANUFACTURING DRAWINGS



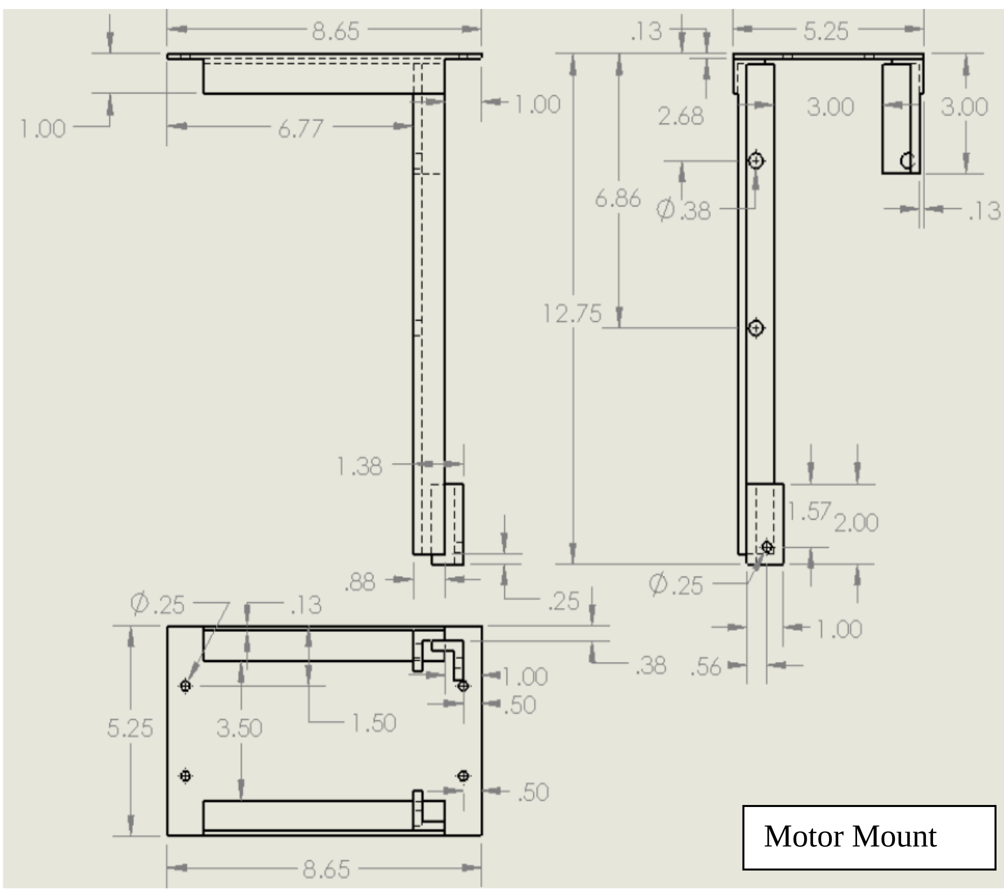


Figure 7

Bill of Materials

Budget (Proposed)		
Item	Qty	Price
Complete Motorcycle	1	$250.00
Electric motor (used)	1	$300.00
Batteries	4	$360.00
Charging system	1	$70.00
System controller (used)	1	$230.00
Throttle system	1	$60.00
On/off system	1	$10.00
Kill switch plunger	1	$10.00
300 Amp fuse	1	$8.00
48V pre-charge resistor	1	$10.00
DC/DC converter	1	$10.00
#40 Chain and master link	1	$13.00
Drive Sprocket	1	$30.00
Driven Sprocket	1	$30.00
10ft 4 gauge weld wire	1	$22.00
Copper crimp lugs	14	$6.00
4' 3/8" angle iron	2	$16.00
1/4" stainless steel stock	1	$50.00
Total		**$1,435.00**

Table 1

BUILD AND TEST

Discussion of the Manufacturing Processes Utilized

The goal of the project centers around creating a kit that the average person could successfully assemble. Therefore, the processes involved include simple processes such as cutting and drilling – while avoiding more advanced processes like machining and welding. As for making the kit itself from a manufacturing standpoint, the most common processes by far are precision metal cutting, and precision metal drilling. The kit is a bolt together kit, that includes bolting to the motorcycle itself as well as bolting individual pieces together to form the components of the kit. Naturally, this process allows for components that are extremely strong and easy to assemble with hand tools. However, drilling assembly holes that are precise becomes extremely important, as the holes must line up nearly perfectly to accept a bolt. As a result of this, the most important part of the manufacturing process becomes precision measuring. The mismeasurement of a bolt hole location will result in a snowball effect, negating other bolt hole locations even though said bolt holes are properly placed. Although not necessarily difficult to properly measure using tools like a digital caliper and straight edge, it quickly became the most time-consuming part of the build. In some stages, the usage of metal stencils were used to ensure proper bolt hole placement before drilling.

This involves making a quick replica of the work piece to ensure measurements are correct before performing the manufacturing action on the work piece itself.

The precision cuts were made using a handheld metal cutting wheel. When possible, a table-top mounted wheel was used instead to create a straighter cut. As for the bolt hole drilling, a vertical drill press was used in conjunction with various sized cobalt metal drilling bits. When ran at a low speed with proper lubrication, metal drilling bits like these are capable of extremely precise drilling. The bolt holes located on the motorcycle frame itself were drilling using a handheld unit due to the odd geometry present within the motorcycle frame. The rear sprocket of the bike is a custom sprocket CNC milled by a company in lower Tennessee. This milling is completed with a variety of recorded specifications specific to this bike such as the bolt hole mounting diameter and intended chain usage. This type of component can only be milled by a computer-controlled machine to ensure symmetry for such an integral part of the motorcycle.

The wiring portion of manufacturing becomes easy once the correct wiring diagram is available. The process involves crimping wire of two different gauge types, those being 4 gauge and 16 gauge wiring. The type of wiring used can carry up to 600 volts, more than enough for a 48V system such as this. The wire must be measured individually for its application, cut to length, and a copper lug of either 5/16” or 3/8” diameter crimped on each end. After this, the lug is heat-shrunk on and covered with electrical tape. The process then becomes connecting the wiring with bolts and nuts. As for the mounting of the system itself, a wooden plywood board ¾” thick is used as a mounting point for its non-conductive properties. To cover the system a custom metal brake was made, and an aluminum sheet was bent to form a cover.

TEST PROCEDURE AND CRITERIA

The motorcycle was tested within 4 different categories:

- Range (measured in miles)
- Acceleration (measured in seconds)
- Braking (measured in seconds)
- Maneuverability (Qualitative test)

The criterion for these tests relies either on earlier calculations based upon component specifications, the range test was conducted in this fashion – or data from the specifications from the original motorcycle, the acceleration and braking test use this data. The final test of maneuverability is strictly a qualitative test based on one’s own reasoning. This is simply because the original motorcycle manufacturer never provided data of this kind when it was manufactured. However, all conclusions will be reenforced by numerical values whenever possible.

Range

The range test will be conducted using a stretch of road premeasured using google maps. Once the length of road is known, the bike is driven from a full charge to no charge by completing laps on the premeasured stretch of road. A mark was made on the throttle to ensure a constant current draw from the battery by maintaining constant speed. This is somewhat unrealistic to actual driving or commuting conditions but will result in a more conservative range estimate. A conservative estimate is desired simply to provide a safer specification. The length of test road is shown below.

Figure 8

Acceleration

The Acceleration test for the bike will be conducted from 0 to 30 MPH. The test will be ran using a GPS speedometer and times recorded using video footage from a screen recording of the speedometer as well as a third-party recording using a stopwatch to compare values. The test will be ran a total of 5 times and the values recorded resulting in an averaged final value. The degree of improvement or deterioration will be determined by the original values for the motorcycle provided by the manufacturer. Through research, I found the original 0 to 30 MPH time to be about 3.8 seconds.

Braking

The braking test will be conducted the same as the acceleration test, only in reverse. Times will be recorded in the same fashion as acceleration and compared to manufacturer specification a total of 5 times and the average will be the final value. Through research, I found the original 30 to 0 MPH time to be about 3.5 seconds.

Maneuverability

The maneuverability test is purely a qualitative test. The bike will be ridden through a series of cones to test handling. The result will utilize previous motorcycle experience to determine ride quality, feel, and confidence level while riding – In addition, this test is performed last as a way to give final impressions about the bike after riding it for some time.

TEST RESULTS AND FINDINGS

Range

The range test took place on the section of road shown above. A single lap on this stretch of road is 1,504 feet. The bike was run from full charge to zero and was able to complete approximately 71 laps.

$$71\ laps * 1{,}504\ feet = 106{,}784\ feet$$

$$\frac{106{,}784\ feet}{5{,}280\ feet} = 20.22\ miles$$

The calculated range for the motorcycle setup is approximately 32 miles. This is obviously short of the calculated goal by roughly 12 miles. This result can be explained by a few different issues. The first of which being the batteries. The batteries used on the bike are a budget option and the materials used and the battery specifications reflect this. The amp hour rating of a battery like this is lower than other more expensive batteries in the same class. Ultimately, a higher amp-hour rating results in a longer lasting battery. I believe this is the main factor in failing to reach the calculated value. An additional factor in failing to reach the calculated range goal are older parts of the motorcycles rotating assembly that need replacement. The older bearings and axles used on the bike were not replaced due to the tight budget of the project. Replacing these components would greatly reduce the friction present in the system and result on less force for the motor to overcome, resulting in less power drain over time. Although the range test fell short of the calculated goal, the 20 mile range still meets the scope of the project. The University of Cincinnati campus has a perimeter of nearly 2 miles, and a 20 mile daily range would more than suffice for the consumer targeted in the research. Overall, the failure to reach the calculated range goal is a problem that can be overcome purely by increasing the budget. However, if more money was to be spent on the project, I feel that replacing the lead acid batteries with lithium-ion is a better investment to solve this problem.

Acceleration

The acceleration test results are as follows:

Test	t (sec)
1	1.66
2	1.79
3	1.73
4	1.68
5	1.72
AVG	1.716

Table 2

The results of the acceleration test show a stark increase in acceleration. The reason for this is quite straight forward. The motor used in the project makes less overall horsepower but produces maximum torque almost instantly. This change alone can explain such an increase in acceleration. Moreover, the conversion process resulted in a large decrease in overall weight, approximately 170 pounds worth. These changes working in unison result in a large increase in acceleration. This result further increases the usability of the bike, inspiring more confidence in the rider.

Braking

The braking results are as follows:

Test	t (sec)
1	3.88
2	3.52
3	3.82
4	3.80
5	3.65
AVG	3.73

Table 3

These test results show a comparable result to the bikes original performance. However, the original motorcycle as it came from the factory utilized a front disc brake, and a rear drum brake. The finished converted bike utilizes only the front brake, so this data actually shows an improvement in braking capability. This can be explained by the weight loss through the electric conversion process. The bike shed approximately 170 pounds from the original, and less mass equates to a shorter stopping time even though the rear brake is no longer utilized.

Maneuverability

The maneuverability of the motorcycle is improved overall. Although this is simply a qualitative assessment, the weight reduction of the bike makes it incredibly easy to handle. The motorcycle can be pushed by anyone of average strength, the bike can easily be ridden by a person of basically any size without fear of losing control. Ultimately, the motorcycle feels easier and lighter to ride than a traditional motorcycle and for this, the bike is marked as an improvement over the original design.

PROJECT MANAGEMENT

BUDGET, PROPOSED/ACTUAL

Budget (Proposed)		
Item	Qty	Price
Complete Motorcycle	1	$250.00
Electric motor (used)	1	$300.00
Batteries	4	$360.00
Charging system	1	$70.00
System controller (used)	1	$230.00
Throttle system	1	$60.00
On/off system	1	$10.00
Kill switch plunger	1	$10.00
300 Amp fuse	1	$8.00
48V pre-charge resistor	1	$10.00
DC/DC converter	1	$10.00
#40 Chain and master link	1	$13.00
Drive Sprocket	1	$30.00
Driven Sprocket	1	$30.00
10ft 4 gauge weld wire	1	$22.00
Copper crimp lugs	14	$6.00
4' 3/8" angle iron	2	$16.00
1/4" stainless steel stock	1	$50.00
Total		**$1,435.00**

Table 1

Budget (Actual)		
Item	**Qty**	**Price**
Complete Motorcycle	1	$250.00
Electric motor	1	$550.00
Batteries	4	$225.00
Charging system	1	$48.00
System controller (used)	1	$290.00
Throttle system	1	$65.00
Kill switch plunger	1	$9.00
400 Amp fuse	1	$8.00
DC Contactor	1	$45.00
48V pre-charge resistor & diode	1	$18.00
DC/DC converter	1	$20.00
#40 Chain and master link	1	$13.00
Drive Sprocket	1	$14.00
Driven Sprocket	1	$80.00
10ft 4 gauge weld wire	1	$18.00
10ft 16 gauge wire	1	$12.00
Copper crimp lugs	14	$25.00
Steel	N/A	$70.00
Bolts/Washers/Nuts	N/A	$70.00
Total		**$1,830.00**

Table 4

The project ended with an actual budget nearly $400 greater than the projected. During the beginning of the project, the goal was to recycle components whenever possible. However, during the purchasing of major components many of the used components that were readily available just a few months before had become scarce due to random demand. The exact reason for this is unknown, but many components now needed to be purchased new in order to complete the project on time. The motor needed to be bought for full price which was more expensive than the used motors available before. The controller also increased in price significantly over just a few months. These two events resulted in most of the needed budget increase. The final bit of increase came from random bolts/nuts/washers to complete components assemblies.

SCHEDULE, PROPOSED /ACTUAL

Schedule (Proposed):

2/1
Begin purchasing necessary components
Build Motor Mount and Battery Trays
2/1 - 2/10
Mount motor mount and attach engine
Secure drive and driven sprockets
Add chain
2/10 - 2/22
Mount Battery Trays and Batteries
Mount Controller
Mount Throttle System
2/22 – 3/15
Begin Wiring of Systems Components
DC/DC converter
Fuse system and kill switch
3/20 Onward
Testing and further development

Schedule (Actual):

2/7 – 2/22
Parts ordered or obtained
Frame Modifications
Battery Tray
2/22 – 3/12
Motor Mount
Sprocket System
3/12 – 3/28
Wiring
Random Issues
3/28 & Beyond
Testing
Tuning

The proposed schedule and actual schedule show only a few differences, and the start and end time are only a single week apart. The frame modifications needed during the beginning of the project took much longer than expected. A few unexpected shipping delays also postponed the starting date of the project. The last big hurdle came from developing the wiring system. The system I designed before hand was not entirely correct, and led to a few weeks of research and trial and error. Overall, if I were to do the project again, I would add a few extra weeks simply for further development and experimentation.

Sustainability and Material Usage

Generally, the materials usage of the project went extremely well. The project was developed with recycling components and forgotten materials from the beginning. Parts of the battery tray steel was recycled material. The controller, some of the wiring, and the 48 volt DC contactor were previously used components sourced through eBay. All of the original motorcycle components (including the motorcycle itself) were bought for $250 from a junk pile. The entire point of the project centers around sustainability from its creation to the motorcycle's operation. The only needed change to increase sustainability involves increasing the purchasing window of used goods. The used components only become available for purchase when an individual makes them available, they cannot be bought at just any time. This unfortunately means many of the components I would have liked to purchase used, needed to be purchased new due to the strict schedule I was operating on.

CONCLUSIONS

Ultimately, the motorcycle exceeded three of the four metrics. A single metric failed to be met, however, the solution to this problem is simple – increase the budget. The motorcycle successfully offers environmentally friendly transportation at a cost close to the proposed budget. The acceleration, braking, and maneuverability of the motorcycle all improved after the conversion process. Additionally, the motorcycle became significantly easier to operate, as the weight decreased by approximately 170 pounds and the clunky transmission was replaced by a single gear. This ensures ease of use and user-friendly attributes that quickly make anyone a proficient rider in addition to making already compact transportation even more compact.

The assembly of the custom components is extremely easy to complete and install on the motorcycle. Only the use of a few hand tools are required for installation. Moreover, replacing damaged parts becomes a simple trip to any general-purpose hardware store instead of involving a weld repair. The bolt system keeps costs down which increases the affordability of the bike greatly. Each of these attributes further ensures ease of use and inspires confidence within the customer. All of these factors have been achieved in the kit by exceeding the budget by a few hundred dollars – still making this kit thousands of dollars cheaper than the closest competition. This is in addition to completing the project only one week behind schedule. For these reasons I am concluding the project as a successful prototype of the original design.

If I were to do things differently or make another prototype – a few things stand out. The first being an increase in budget exponentially increases the usability of the motorcycle. This first prototype was a success regarding the scope of the project. However, I believe an increase in budget could greatly increase the scope, and therefore the validity of the product. I am currently planning a second attempt utilizing custom made lithium-ion cells as a replacement to the lead-acid cells. The current plan could result in a range greater than 150 miles. Although, this plan requires a significantly higher budget – I believe the success of this first prototype demonstrates the validity of such an endeavor. The only thing that I believe needs to be done to improve this version includes purchasing higher quality lead-acid cells, as well as replacing all rotating parts on the motorcycle itself to reduce friction. Ultimately, the project proved the concept well and will lead to a second prototype.

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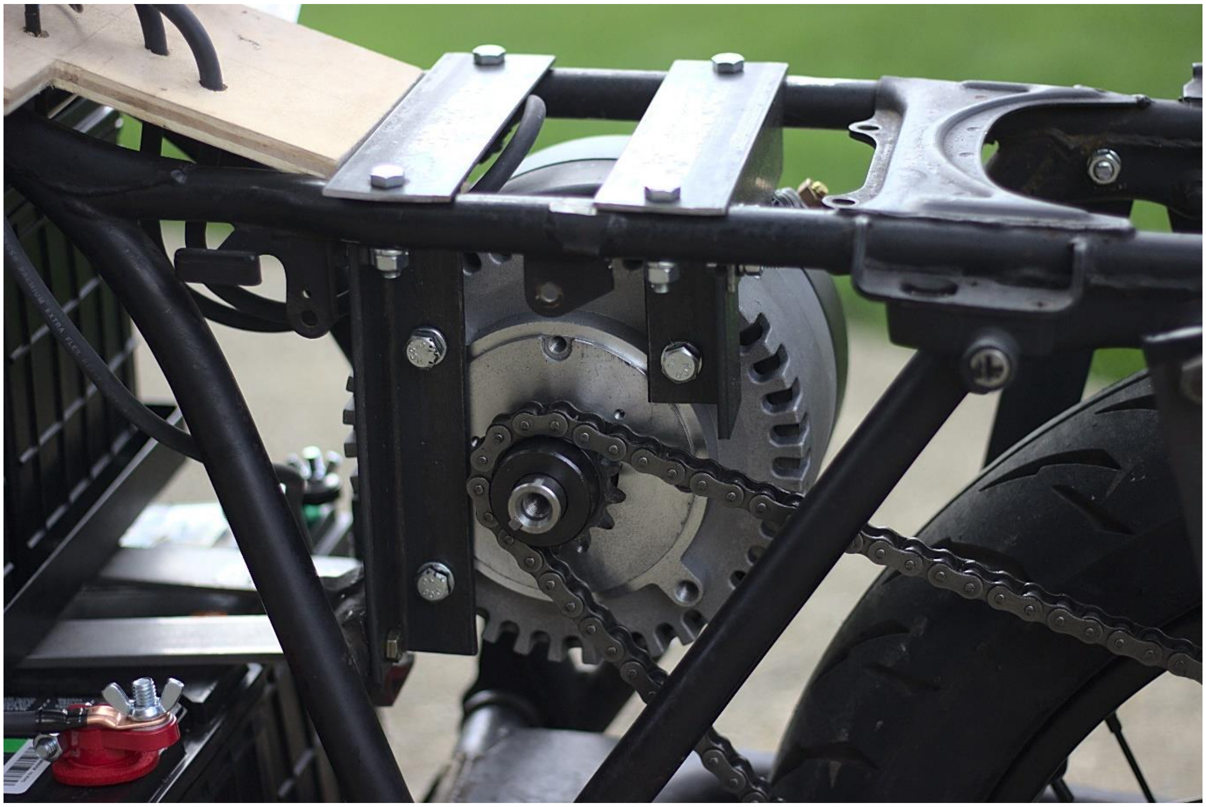
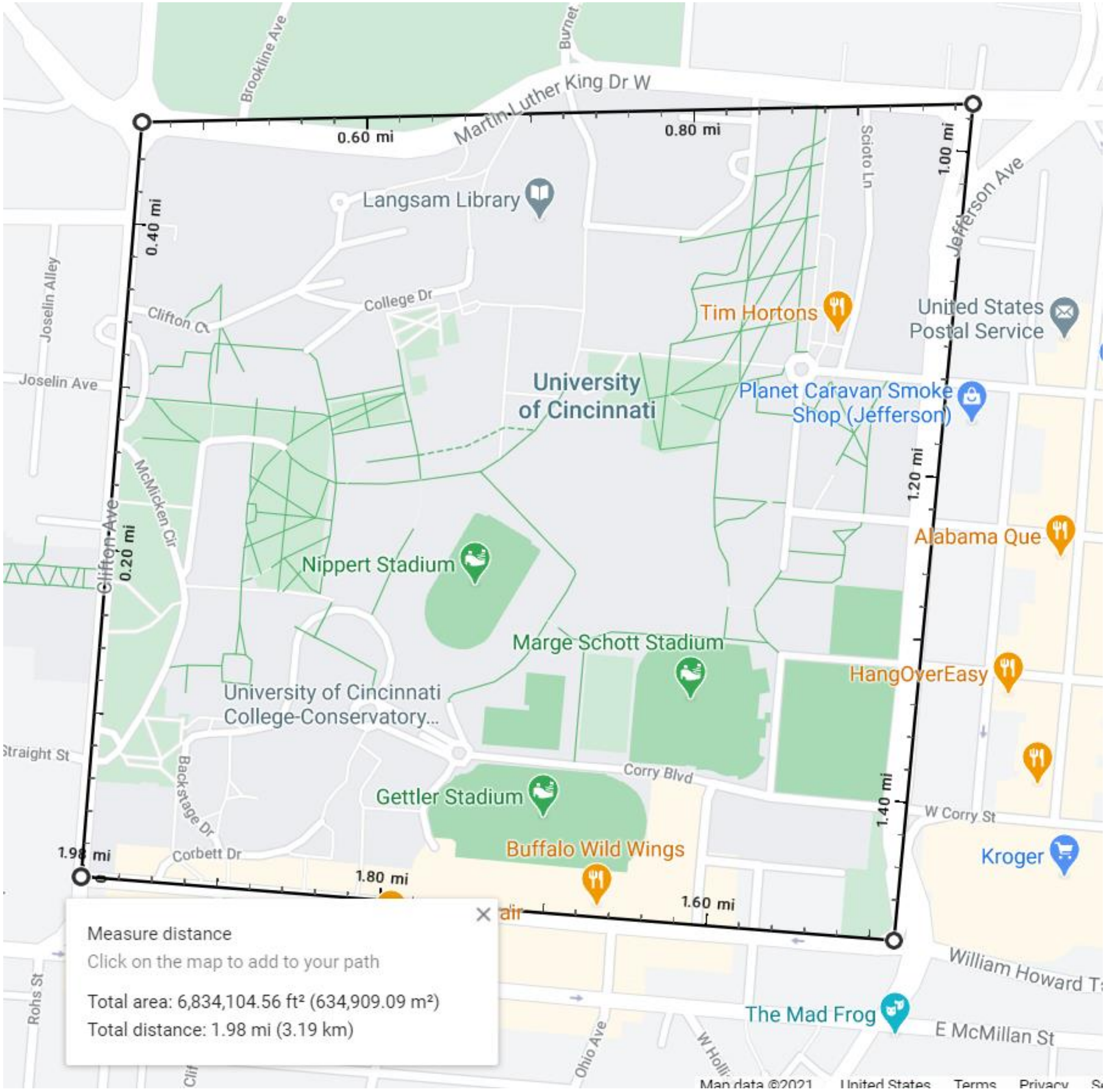
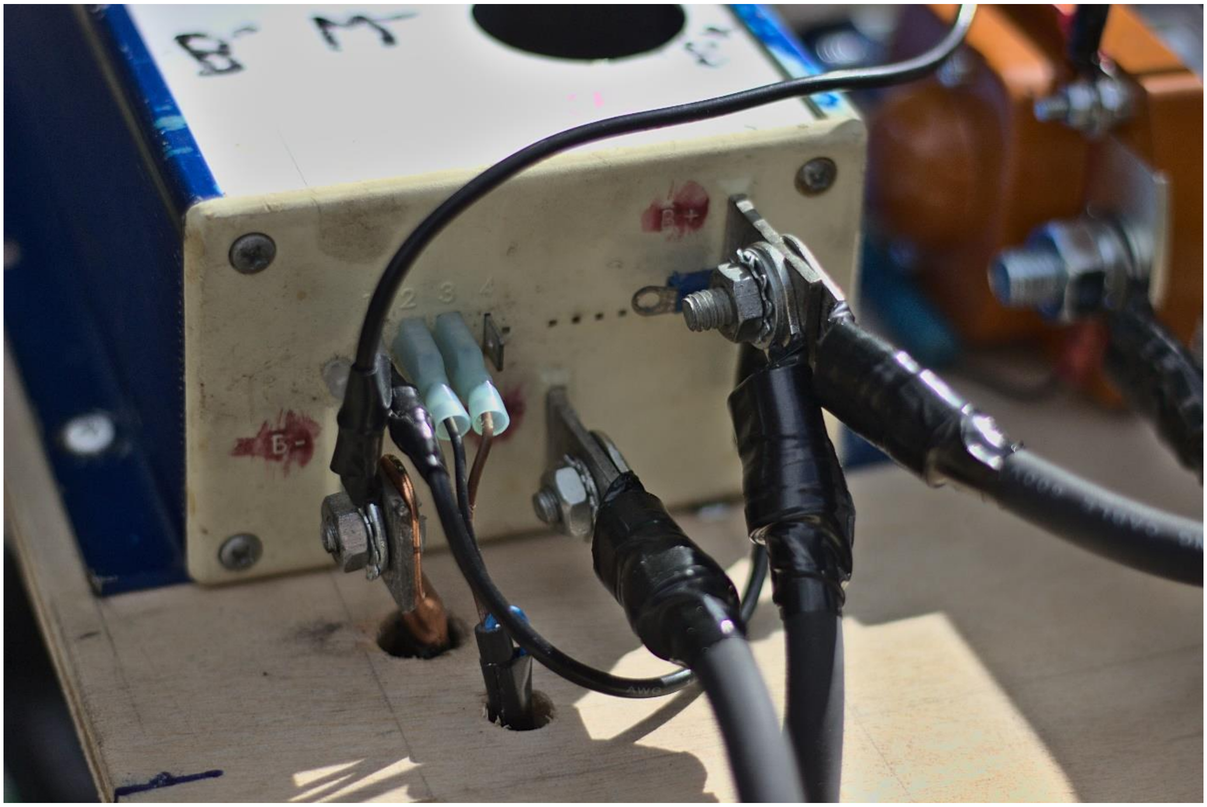
APPENDIX


CRAFTSMAN
THRIFTY
STANLEY
RYOBI
RYOBI




RYOBI
RYOBI
4" Angle Grinder
4" Angle Grinder
RYOBI
COOLANT TRAY


Martin Luther King Dr W
0.60 mi
0.80 mi
1.00 mi
Langsam Library
0.40 mi
College Dr
Clifton Ct
Tim Hortons
United States Postal Service
Joselin Ave
University of Cincinnati
Planet Caravan Smoke Shop (Jefferson)
1.20 mi
Clifton Ave
0.20 mi
McMicken Cir
Nippert Stadium
Alabama Que
Marge Schott Stadium
HangOverEasy
University of Cincinnati College-Conservatory...
Straight St
Corry Blvd
Gettler Stadium
1.40 mi
W Corry St
Buffalo Wild Wings
Kroger
1.98 mi
Corbett Dr
1.80 mi
1.60 mi
Measure distance
Click on the map to add to your path
Total area: 6,834,104.56 ft² (634,909.09 m²)
Total distance: 1.98 mi (3.19 km)
William Howard T
The Mad Frog
E McMillan St
Jefferson Ave
Scioto Ln
Joselin Alley
Brookline Ave
Backstage Dr
Ohio Ave
Rohs St
Map data ©2021
United States
Terms
Privacy


B+
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