# Front-Wheel Removable Electric Bicycle Motor

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*ENPH 479*

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*Jan 7th, 2013*

# I. EXECUTIVE SUMMARY

The Front-Wheel Removable Electric Bicycle Motor project is aimed towards building a removable all-in-one unit for a friction-drive system containing the battery, motor and the motor controller for the front wheel of a bicycle, and this will be a universal motor package for all regular bicycles.

To achieve this goal I designed a firm frame on which could hold both the motor and the battery. In this design, the bicycle could have a speed of 20km/h and the maximum power output of 200W, which basically achieved the requirements of 25 km/h and 200W provided by sponsor. With 4 batteries, this device could last 1 hour.

During this project, three different designs were designed, manufactured and tested in real situation. After two failures, I built a working prototype, and then I started working on the special requirements of speed and power.

The final deliverable includes a working prototype that could be easily mounted on the front fork of the bicycle, and a final report that will indicate every detail in this design.

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## 1.0 INTRODUCTION

In our modern life, oil-based motor dominate the methods of people's daily traveling. However, with the spread the globe warming effect, people realize that the clean power is more important for our daily life. Without or with less carbon dioxide emissions, our air can be cleaner. So more and more electricity-based transportations are coming into our life.

Bicycle could be considered as the first useful human-powered transport. With year's effort, people use hub motor to build the electric bike, like the bicycle with hub motor in rear wheel as shown in Figure 1, or in front wheel as shown in Figure 2.

Based on the above examples, we can find that hub motor could assist people on riding a bicycle, but based on people's riding experience with hub motor, this hub-motor type bicycle has three major disadvantages. First, the weight of the motor is very heavy. Second, the installation and maintenance of the hub motor is complicated. Last but not the least, the price of this ebike kit is expensive, usually more than $500 US dollar.

Due to these reasons, some people invented something new, for example the rear mount power assist as shown in Figure 3.

**Figure 1: Smart ebike (hub motor in rear wheel)**


**Figure 2: Lexus ebike (hub motor in front wheel)**

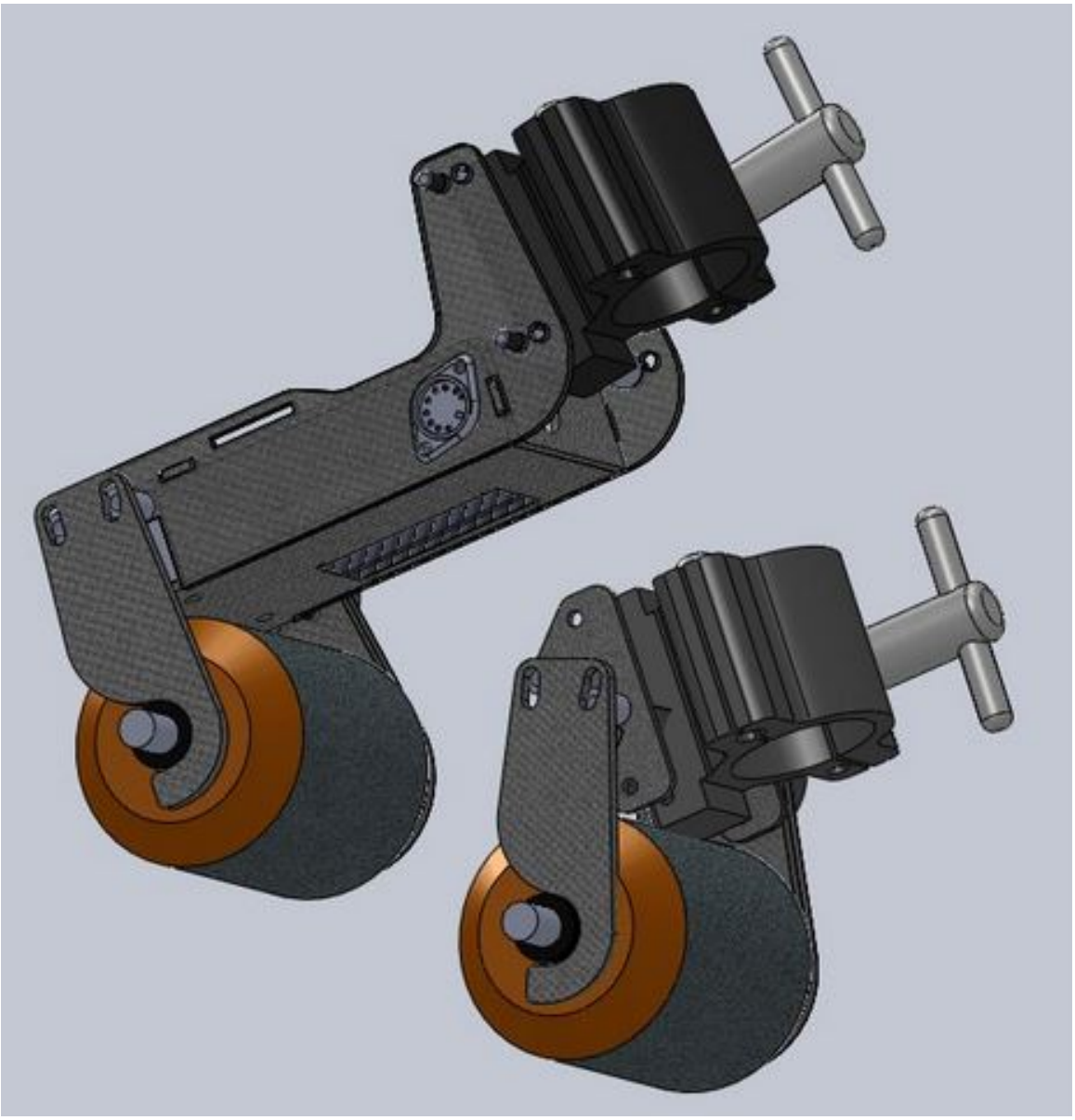


**Figure 3: Rear mount power assist**

In these kinds of designs, there is a common disadvantage: the installation of this device is very complicated due to that the battery and the motor are separated. One more disadvantage, there are lots of modern designs of bicycle with different seat design, which as shown in Figure 4. As a result, this power assist shown in figure 3 could not be installed under the seat.

Therefore, sponsored by Dr. Andrzej Kotlicki, I will provide a new, rationale design of the power assist on front wheel, which will be an all-in-one unit with the battery and the motor together, with lightweight and one-step installation on the bicycle.

**Figure 4: Audi ebike**

## 2.0 PROJECT OBJECTIVES

The SMART (Specific, Measureable, Action-orientated, Realistic, and Time-bound) objectives of this project can be summarized as follows:

- Develop designs with SolidWorks in computer and simulate the designs by Nov 2nd 2012.
- Build a prototype with appropriate material and parts by Nov 16th 2012.
- Edit the front fork mounting design, and tune up the system with the speed and power requirements by Nov 30th 2012.

- Produce a recommendation report at the end of the project to provide a concise summary of this design by Dec 23rd 2012.

# 3.0 DISCUSSION

## 3.1 Theory

This design will be totally based on the theory of friction. The surface between the running motor and the rubber tire on front the wheel is very rough, there will be a high friction coefficient. I could use this sufficient friction to give the bicycle a power boost.

Also, this design will involve the theory of inertia. Once the motor is running, the reaction of the inertia of this motor will automatically pivot the arm and the motor will automatically have contact with the rubber tire. See figure below,

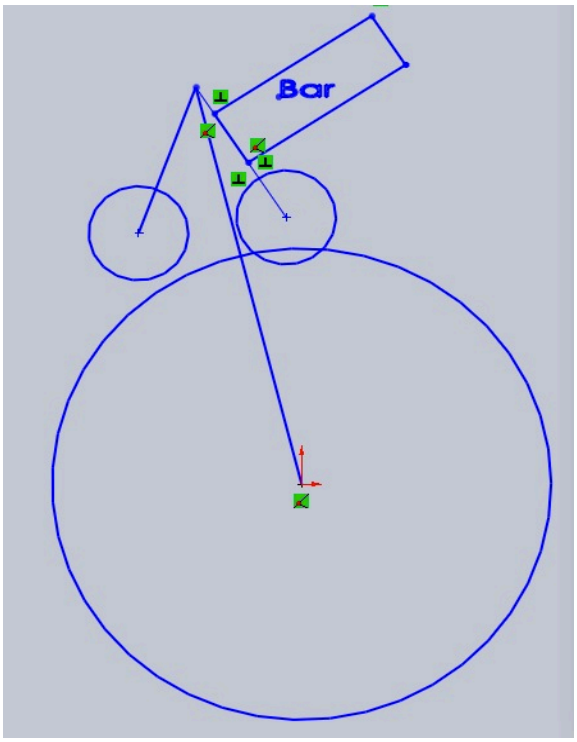



**Figure 5: Theory Graph**

There is a small gap between motor and the tire. When motor starts running, the inertia of the motor will make it contact the tire on the wheel. When they engage together, the motor runs much faster than tire in the initial condition, so the motor will go across the central line which is from pivot point to the axial of wheel. Two small bars will hold the motor arms in the position as shown, so the motor will keep speeding up the bike. When the motor stops or the speed of the tire is much faster than the motor, two springs attached on the motor arms will pull the motor back to the initial position, and ready for the next acceleration operation.

## 3.2 Few Designs

There are three designs totally, as shown in Figure 5, 6 and 7.

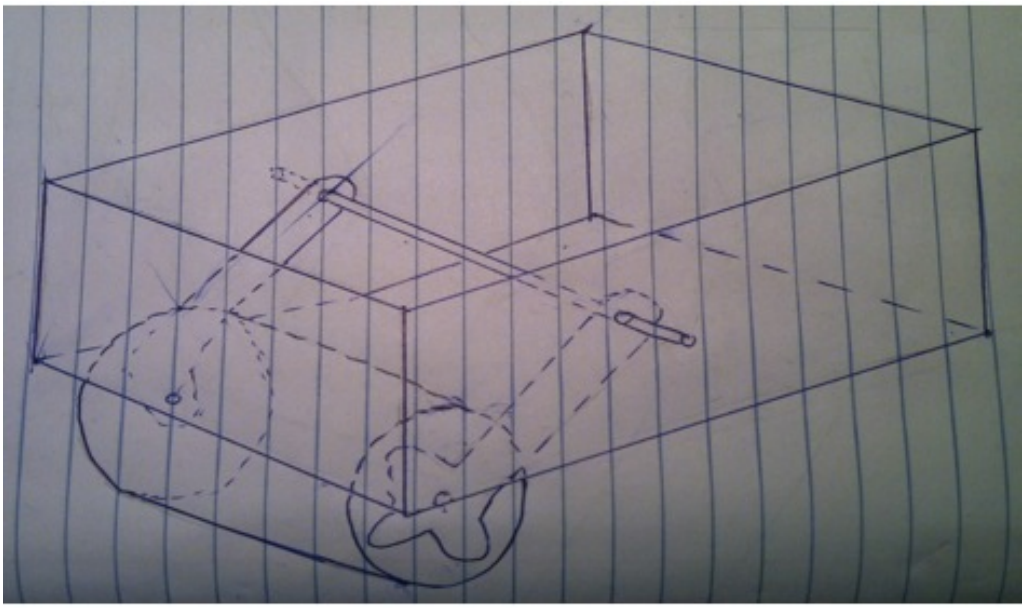


**Figure 6: Original design (motor within a box)**

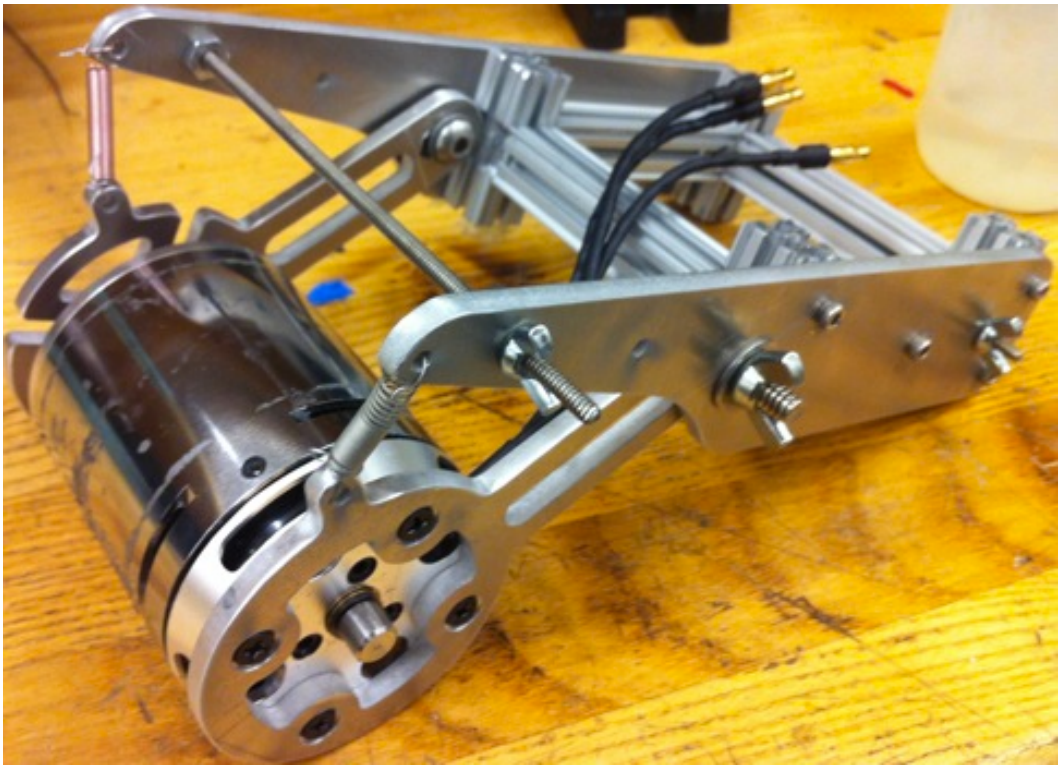


**Figure 7: Second Deisgn (With 2 Short Arms)**

**Figure 8: Third and Final Design (With 2 Long Arms)**

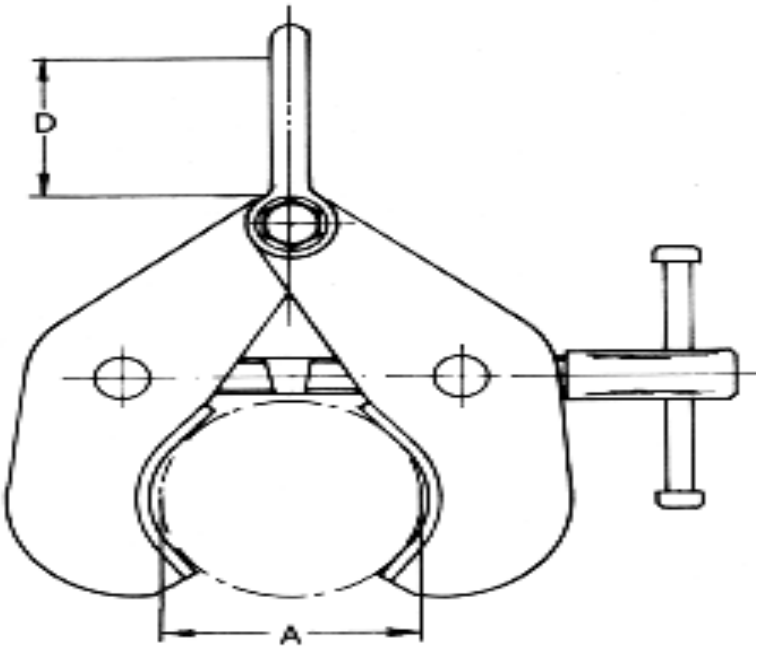



**Figure 9: Clamp On The Rod Of The Frame**

With two long arms, this device can be placed firmly on the fork of the bike, and the two clamps on the end of each rod will stabilize the device on the forks. See graph below,

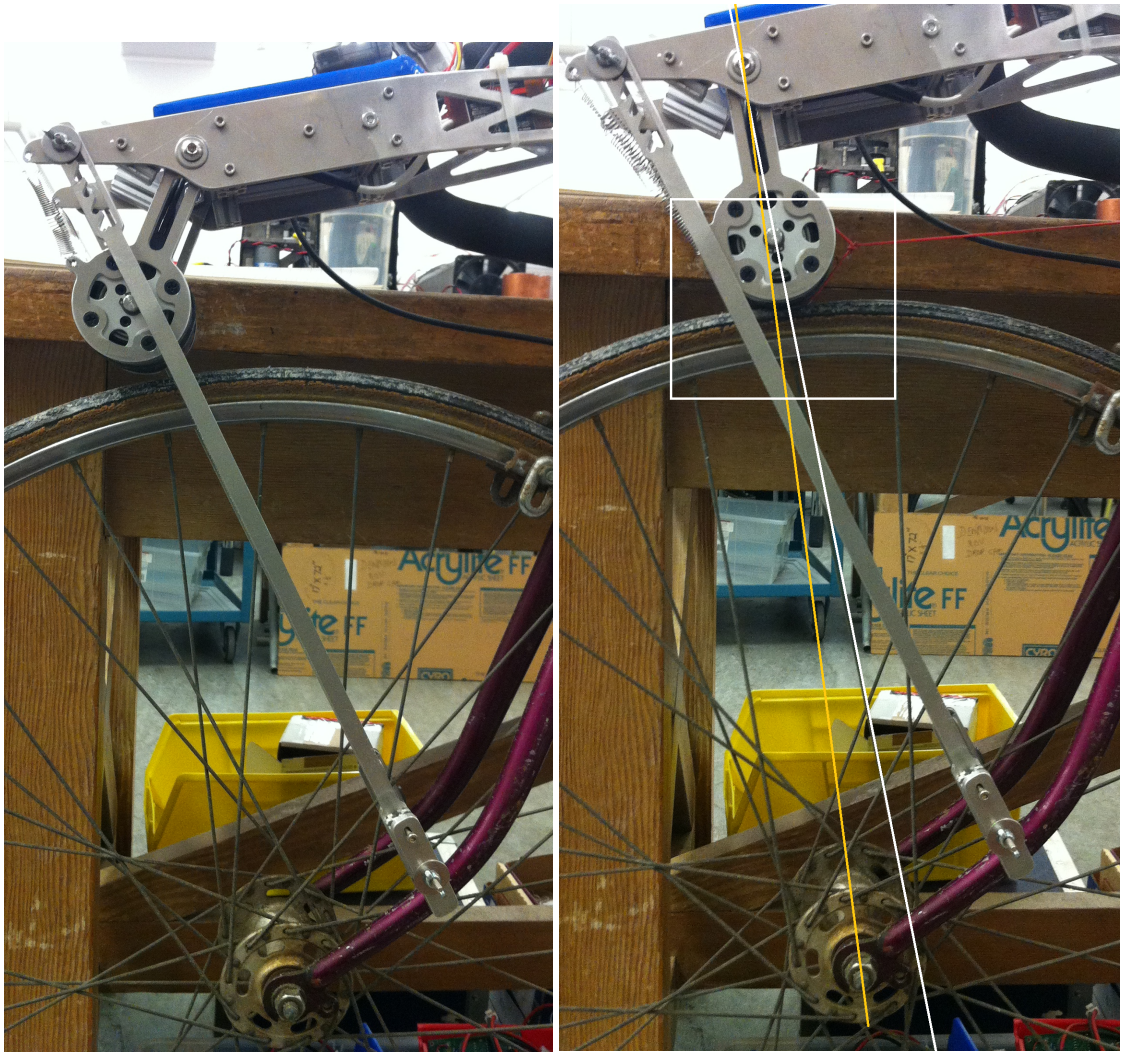
**Figure 10: Clamps At The Ends Of The Rods**

## 3.3 Results

By building up the prototype based on the final design, the device can drive the bike to a certain speed.

## 3.4 Discussion of Results

Mechanism Part.



**(a) Disengage** **(b) Engage**

**Figure 11: Comparison In Operation**

The theory is discussed in the section 3.1. The motor passes the central line when it is running.

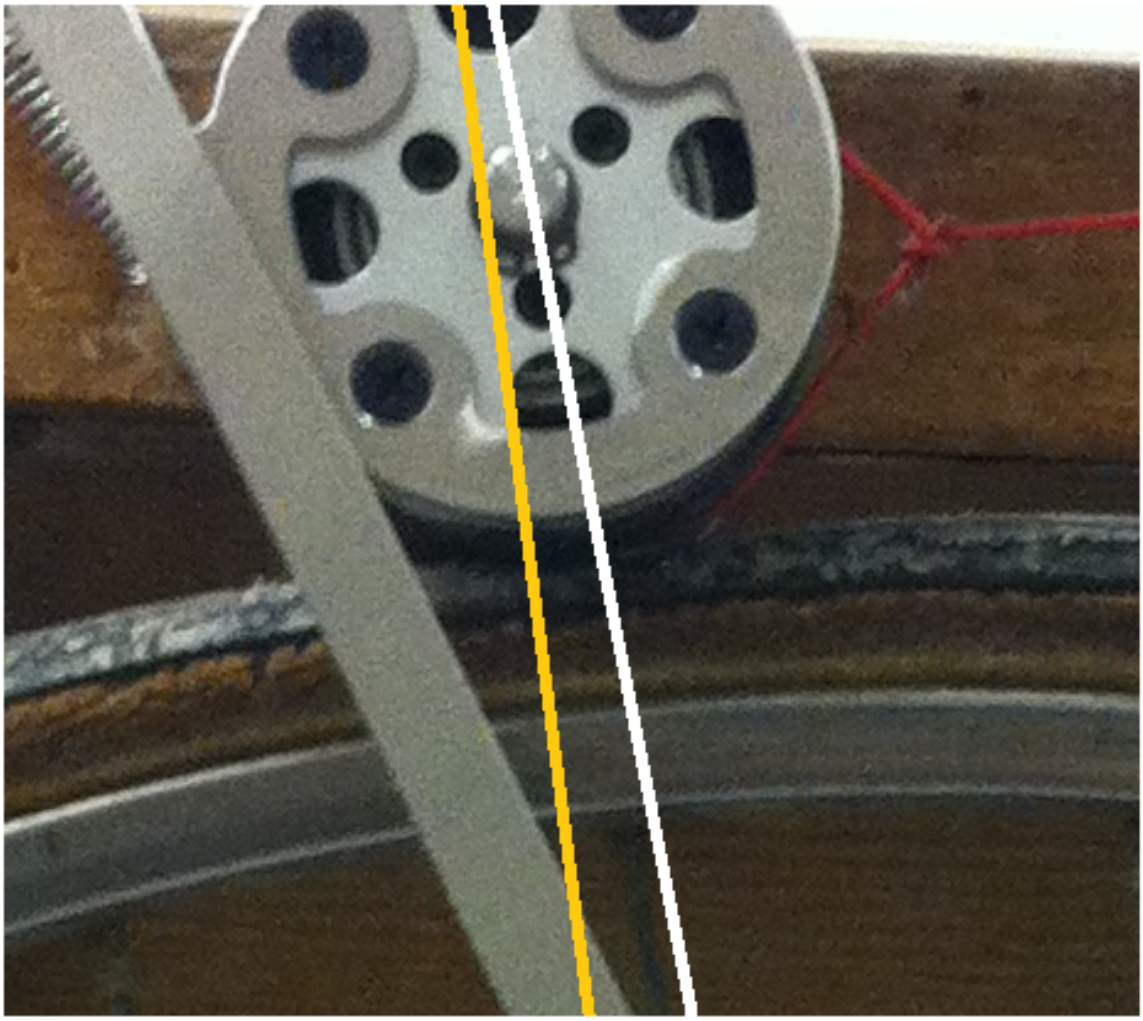


**Figure 12: Connection Part**

As shown above in the figure 12, that is where I can get the frictional force to drive the bicycle and the rider.

Power Part.

Based on the requirement by the law in Europe, the main objective is to consider the power and speed output.

After the prototype is built, by using iPhone app “BikeBrain” which is a GPS based bike route calculating software, I took some measurements with

running this motor when I operated the bicycle. There will be sets of graphs based on the measurements data.

For 1 trial, my maximum speed is 20km/h, and the distance takes speed to zero is around 50 meters.

$F_f d=mv^2/2$ v=20km/h=5.56m/s

So $F_f=mv^2/2d=32.7N$, this is the friction between ground and the tire. Then I can find the power for this bike at speed 20km/h, which is P=Fv=182W, and this is the output power of this device to speed up the bike to 20km/h.

In the mean time, I used a current-measuring device to get the current value when the motor was on, whose average value is 10.2A, by timing the voltage of the battery, 22.4 V, the total power of the motor is 228.5W.

In additional, I can provide the motor efficiency that is 80%.

## 4.0 Conclusions

Take a look at this project as a unified entity; it comes from nothing to working properly. With failures, it comes more and more reliable. Although there are some small problems that need to be modified, such as the maximum speed, it is already a finished product that can be used with significant conveniences in our daily life. With four 2.65kwAh batteries connecting parallel, the device can last one hour at a speed of 20km/h.

# 5.0 APPENDICES & REFERENCES

## 5.1 Data Measurement Graphs

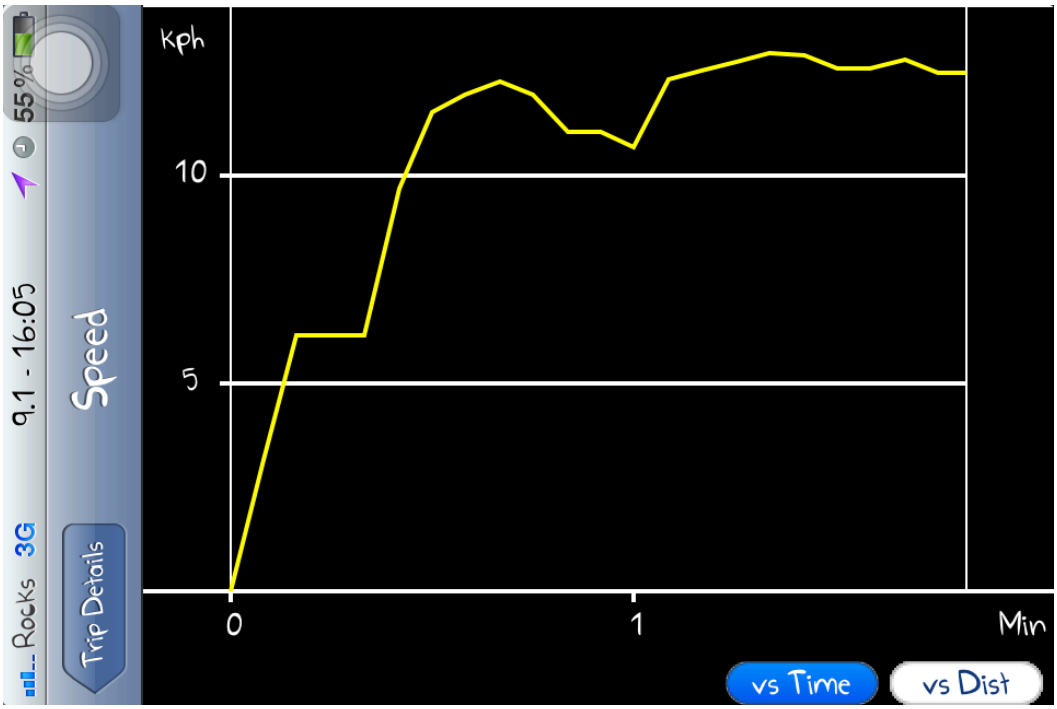



**Figure 13: Speed VS Time (without Motor Running)**

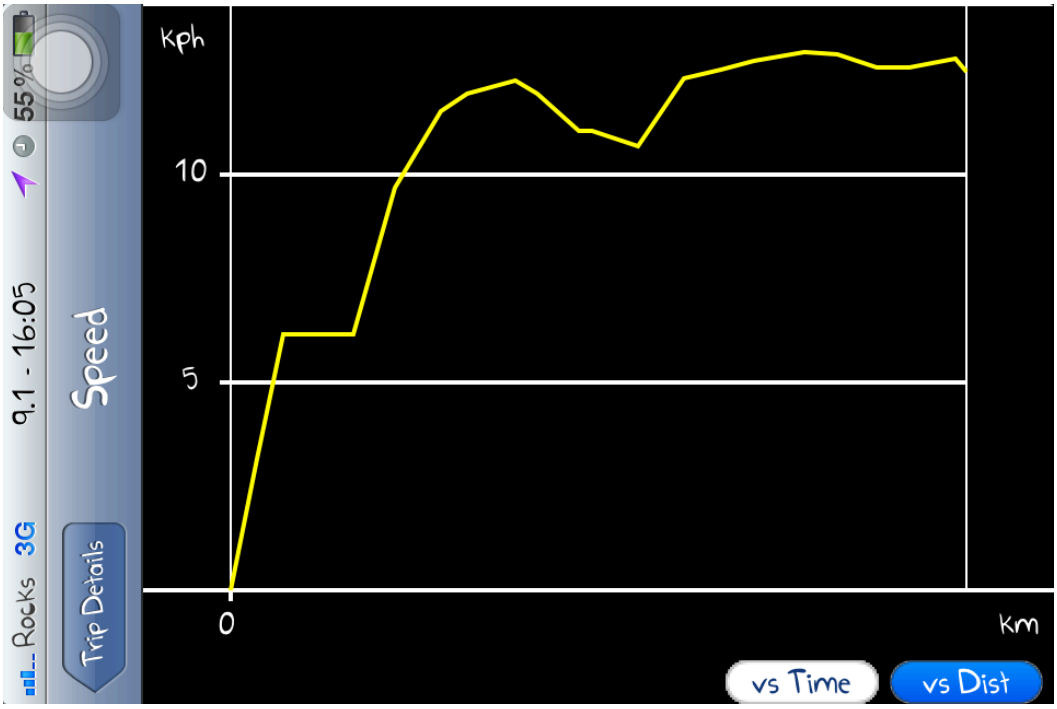



**Figure 14: Speed VS Distance (without Motor Running)**

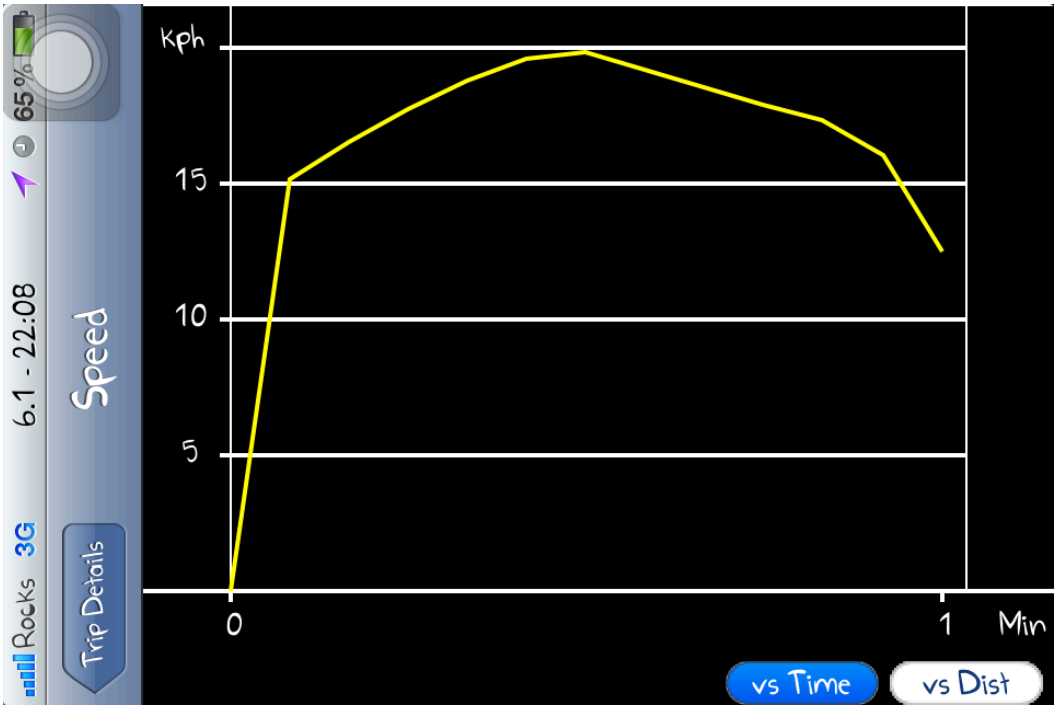



**Figure 15: Speed VS Time (with Motor Running)**

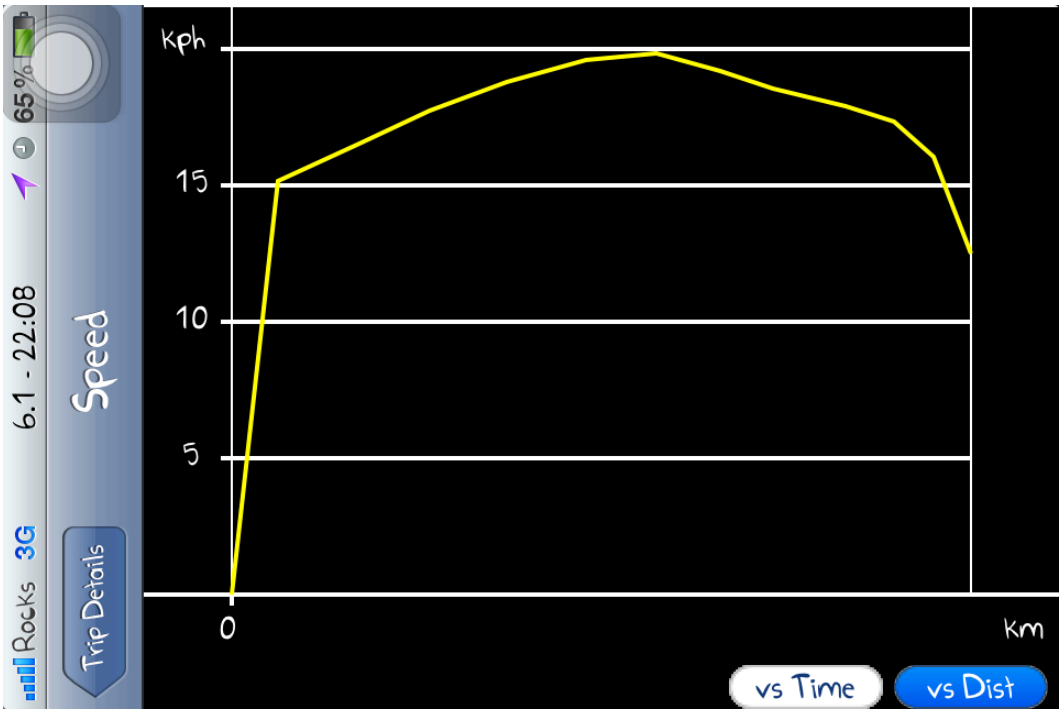



**Figure 16: Speed VS Distance (with Motor Running)**

**The motor is running after speed of 15km/h**

## 5.2 List of Deliverable

### 5.2.1 Original SolidWorks design files

### 5.2.2 Recommendation Report

### 5.2.3 A properly working prototype

## 5.3 Budget

**Table 1: Cost and Budget**

| Item | Quantity | Cost | Purchased By: | Funded By: |
|---|---|---|---|---|
| Brushless Outrunner Motor | 1 | $75.77 | Bernhard | ProjLab |
| Programming Box | 1 | $9.91 | Bernhard | ProjLab |
| Speed Controller (OPTO) | 1 | $73.58 | Bernhard | ProjLab |
| Servo Tester | 4 | $16.64 | Bernhard | ProjLab |
| EMS Express to Canada | 1 | $43.43 | Bernhard | ProjLab |
| Waterjet-cut parts | 10 | $20.00 | Bernhard | ProjLab |
| A used bicycle | 1 | ? | | Dr. Kotlicki |
| Total Cost | | $238.31 | | |

## 5.4 References


- Rear mount power assist figure http://www.eboo.st/
- Ebike figures

  http://www.behance.net/gallery/smart-ebike/783003

  http://gadgeticworld.com/2012/08/30/5-best-e-bikes-by-the-automakers/

  http://www.autonet.ca/auto-news/eco-friendly-news/2012/05/17/audi-e-bike-worthersee-prototype/
- Theory

  https://sites.google.com/site/commuterbooster/how-does-it-work