THE UNIVERSITY OF BRITISH COLUMBIA OKANAGAN CAMPUS

FACULTY OF APPLIED SCIENCE, SCHOOL OF ENGINEERING

ENGR 499 Capstone Project Definition Report: Open Source Recumbent E-Trike

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1. Project Introduction

Kelowna has been growing at an incredible pace in the past few years (Western Investor Staff, Castanet, 2022), and unfortunately the transportation infrastructure and options in the city lagged heavily behind the population's needs (Seymour, 2021). This problem has not gone unnoticed by the general community, and the demand for answers to these problems has been consistently on the rise. Between the recent rise in gas prices and many of the costs relating to the use of private cars, car transport as a main form of transportation is not viable for many of the population. This resulted in a great increase in the number of people reliant on the public transportation system. Unfortunately, this uncovered many of the faults within the system. These range from the lack of sufficient distribution of transit lines, which the residents of areas such as Quail Ridge felt especially, to issues with safety and punctuality (Barnes, 2022). With all these issues affecting our community, especially the city's ever-growing student population, we set out to resolve this issue by designing, manufacturing and electrifying an open-source python recumbent trike. By creating an easily replicable design and manufacturing process for a safe and efficient trike, we are offering that as a solution for the Kelowna population. Our goal is to create a two-part process in which every individual following our process would have the option of building a normal recumbent trike and stopping there or continuing with electrifying the trike if they choose to do so. This way we can offer flexibility in tackling the individualistic problems of as many of the residents as possible in the most efficient manner. In addition, our trike capitalizes on the larger global movement of pushing people towards sustainable and eco-friendly lifestyles, ensuring it would appeal to the growing environmentally conscious population.Hence, we wanted to find **a way to address the lack of affordable, accessible, and sustainable ways of transportation for the residents of Kelowna that results in an effective method of public transportation**.

2. Need and Constraint Identification

The initial needs statement was developed based on the client's requirements “A way to address the lack of affordable, accessible, and sustainable ways of transportation for the residents of Kelowna that results in an effective method of public transportation.” was shortened with respect to both the problem and population. Based on our research it was found that the solution is more applicable to individuals with access to the tools to build the trike. The main requirements for the project are to be easily manufactured by anyone and affordable to the general population. The scope of our project was decided on by starting with the greatest population we could think of and methodically reducing that size until we reach a viable size. Initially, we set our scope as the population of Canada. However, the myriad of different legal constraints would expand to a size beyond our capability to quantify and account for. Hence we constrained our scope to the population of Kelowna where the problem is prevalent and with much more manageable constraints on our project. By reducing our target population we are also ensuring that we have an accurate representation of the viability of our solution and that our project can be used as a plausible solution for other cities in British Columbia with similar problems and needs to what we have set out to solve.

There are certain standards set out by the government of BC that are applicable to our project. Motor-assisted vehicles such as bicycles or tricycles must: have an electric motor that is no more than 500 W; have fully operable pedals; not capable of propelling the device at a speed greater than 32 km/hr [19.9 mph]. The engine must not engage when the operator stops pedalling, an accelerator is released, or a brake is applied. A driver’s license, vehicle registration, and insurance are all not required. Lastly, the rider must be 16 years old or more, and a bike helmet must be worn. E-bikes(e-trikes) in British Columbia have to comply with all standards outlined in Motor Assisted Cycle Regulation, BC Reg 151/2002.(Theelectricbike, 2022)

To reach the final deliverable, which is the successful integration of the software aspect of the e-trike(which will be explained later), we need to go through the phases of the project. This project has 4 main deliverables: The Design phase, Manufacturing Phase, the Electrification Phase, and the Software Integration Phase.

2.1 Design phase

The first and most integral part of our project is the design and visualization of our entire process. Initially, we set out to collect as many resources as possible to identify viable processes we can use to achieve our goal. The research and design are critical to set our expectations and creating our timelines for deliverables. During this phase the group was divided into two teams, the mechanical team and the electrical team. By efficiently dividing and delegating the work that better suits our members' abilities and preferences we would be able to best utilize our time and produce results as efficiently as possible. The two teams would work in tandem with each other to ensure adequate communication of all of our requirements and to better our ability to adapt to all our requirements.

The mechanical team took on the responsibility of creating the design for the frame of the trike, material selection, the joinery of the parts, documentation of the manufacturing process, and quality control of the production. All of these tasks were carried out while maintaining constant communication with the electrical team to adapt the design for ease of electrification once we are in the manufacturing phase. In the electrification phase, the design constraints are that the motor should not exceed 500 W. The battery size should not exceed the dimensions of the compartment storage unit, where the motor, and ESC controller circuits are placed.

In the design phase, it is also crucial to ascertain all of the legal requirements that the team would be required to follow, for example, the legal limit on power output for power-assisted cycles. In addition, it is crucial to make full use of CAD, CAM, and CAE software to check for safety factors, and other manufacturing concerns before starting on any processes to minimize and eliminate any potential dangers, redundancies, or inefficiencies. Running simulations during the design phase simplifies and eases the process of material selection as a crucial decision of the design phase.

During this phase, we had to take into consideration two of our main constraints. The first constraint we had to consistently account for is the simplicity/ease of assembly of our design. Due to our intention of making this an open-source project, the replicability of our design was very crucial. This limited our choices of joinery processes, needing to be accessible to amateurs. It also limited the complexity of our design and the parts that we would be able to implement. This also heavily influenced our material selection, as we had to choose materials that could be easily obtained and worked on. In addition, this created much greater pressure for our design to allow greater tolerances as our level of expected precision is very limited. The second constraint we had to grapple with here is the limit on our costs. As our project is intended to be very affordable, the materials that would be plausible for us to use were limited even further. The use of cheap material is heavily emphasized not only to reduce costs but also to account for the possibility of errors during the manufacturing stage causing loss of material that would need to be replaced.

2.2 Manufacturing Phase

A crucial constraint of the manufacturing process of the trike is that it must be easily made using simple instructions and minimal skill. Hence gas metal arc welding was chosen as the main joinery process. Though there are safety risks that must be taken into account, gas metal welding is much simpler than TIG as the welding stick is automatically adjusted by the machine as well as the heat, voltage and feed rate can be preset depending on the material. All of this minimizes the required skill of the operator as well as reduces the chances of human error allowing for better-quality welds. Other safety precautions must also be taken such as ensuring the proper use of protective personal equipment, and welding in a proper environment.

In order to meet the constraints of making the trike as economically and environmentally feasible, parts such as wheels, brakes, and handlebars can be scavenged and recycled from used bikes. Gas metal arc welding is also an economically cheaper option. The manufacturing process of the trike can also be done purely with simple handheld tools, therefore removing the need for industrial machineries such as mills and lathes. The decision of ensuring the need for handheld tools makes it a safe and cheap project for a DIY user.

2.3 Electrification Phase

The electrification phase is the stage in the project where the electrical team will convert the manual trike into an e-trike equipped with a motor, brake, and pedal-driven accelerator. The scope of the need that pertains to accessibility is explored in detail. The electrification of our main requirements was to create an accessible trike for the target audience, where they are able to use it with greater accessibility than the other solutions to the problem that is being tackled.

The main constraints during the electrification phase are labelled in *Table 1*.

Economic Constraints	Environmental Constraints	Social Constraints
Total cost less than $1500	Compatible with Public Chargers	Trike (including the frame and electric components) should weigh less than 70 pounds
Price of the battery should be less $500	Safe disposal of battery	The battery should weigh less than 10 pounds
Price of the ESC should be $500	Effective Temperature variability	The app should be built on the Android and iOS Platform

Table 1: Electrification Constraints

For the economic consideration, the cost of the important electric parts must be within budget, that can also be implemented as an applicable stated in the paragraphs above. The environmental constraints of the electrification process deal with the eco-friendly usage and disposal of the battery or any electrical component presented in the project. The social constraints in the electrification phase deal with the limitations presented between the trike and the driver in a socio-cultural manner.

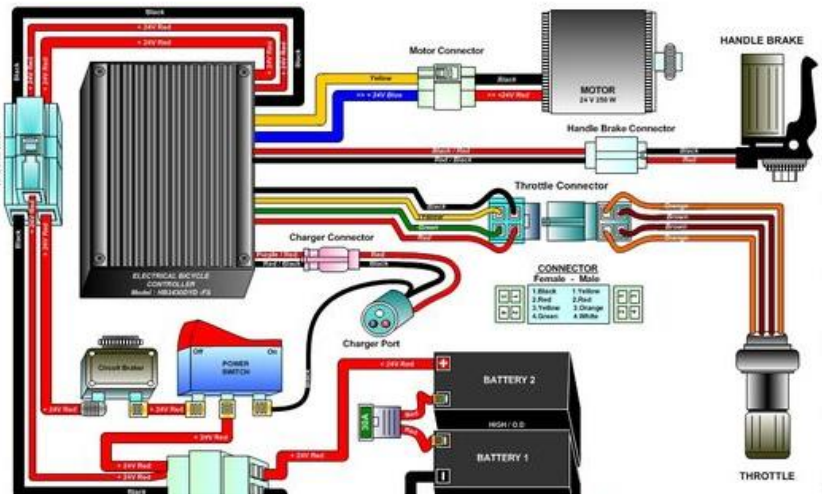

Figure 1: Tentative Electrical Layout

This is the tentative schematic of the electrification layout circuit that will be used to integrate all the electric components together and convert the trike from manual to electric.

2.3 Software Integration and Testing Phase

The purpose of developing an app encircles around facilitating features making the use of the recumbent trike safe and fun for the user. Our group unanimously decided to name the app Skid app. The Skid app will be open source and will be available on GitHub for anyone to access and use. Safety is one of the prime focuses of the design and therefore there are many safety sensors included in the trike. Features such as trike locking, battery life detection and speedometer will be facilitated by the respective sensors. These sensors will be integrated and calibrated with the help of this app thus ensuring the safety of the user. We also plan to include features that help users better plan their journey in advance in an efficient manner. Consider the phone and the Skid app of the user as a Tesla screen, providing useful information such as the battery life and integrated google maps. The battery life detector can update the user with the life of the battery. It will also update the user on how much they have contributed to charging the battery by riding the trike (regenerative braking). The integrated Google maps feature will make navigation easier for the user. The Skid app will also make the user experience enjoyable by including an integrated music app feature enabling the user to listen to music in a safe manner. The app will also motivate healthy living in the community by providing statistics like distance pedalled, calories burned and the amount of carbon emissions saved.

Figure 2: Tentative Logo of SKID App

Before envisioning Skid, our group researched open-source apps that could be used to address the needs defined above. There are many open-source apps and tools available on the internet that help integrate many sensors together, however, there isn't an open-source app that combines sensor integration, google maps integration and health tracker into one. Therefore we intend to combine all the features from different open sources to develop Skid to address the needs and purpose of the trike.

There are a few constraints that need to be addressed while developing the app. The first and foremost constraint is the lack of time to develop Skid in Ios and Android versions. Given the timeline till April, it seems that our team will find it difficult to implement Skid in both Ios and Android versions. Secondly, given the team skillset and the timeline, It is expected that Skid will have unwanted glitches that will require fixing with later updates in the future. Another constraint faced by our team would be integrating open source codes for sensor integration and other features such as google maps and music apps integration onto Skid in the given timeline.

3. Problem Specifications

The major problem that we aim to combat with our design of the python recumbent trike is to tackle the lack of consistent and affordable transportation options in the city of Kelowna. We believe that the recumbent trike designed by our team combats many constraints currently faced in the existing transportation system in Kelowna.

Out of the many shortcomings that the general population faces with transportation in Kelowna, the lack of sufficient city transit lines and consistency is a prominent problem faced by the residents. For example, students living in Quail ridge attending UBC- Okanagan, face a problem of lack of bus options after 5:00 PM (the majority of the classes end after this time.) The only options for students then are to either utilize the taxi service or walk. The use of cab service is not affordable or eco-friendly while walking back long distances is challenging to safety and time-consuming. This issue is not only faced by the students but the residents of Kelowna who are dependent on the city transit for commuting to work, living in much farther areas not lying on the main transit line. Secondly, the frequency of the transit service is low. Thus, increasing the wait times for the service, which is time inefficient.

A possible solution to the inefficient city transit system is the usage of cab service. This solution itself presents major shortcomings. The cab service in Kelowna is expensive and thus is not affordable to the general population for daily use. Secondly, hypothetically if all the residents of Kelowna were to use cab service for daily transit, this would be detrimental to the carbon emission levels, hence not an eco-friendly option.

Another possible solution to the insufficient city transit system is maintaining a personal Vehicle, mostly a car. The shortcomings of maintaining a car are very similar to the usage of cab service. With the ownership of a car comes expenses such as rising gas prices, maintenance, and insurance to name a few. These factors challenge affordability and sustainability for the residents dependent on the city transit system. Secondly, a hypothetical rise in car usage will lead to increased traffic jams and challenge city parking and highway infrastructure.

The open-source python recumbent trike designed by our team acts as a perfect solution to these problems stated above. The trike offers a perfect solution to inefficient city transit lines and frequency. The user of the trike does not need to depend on the city transit system at all. The trike has been designed considering British Columbia road safety regulations and the comfort of the user. With the help of the trike, the user can reach any destination within the city, without the worry about the frequency of city transit. Since the trike is electrified, the user will not find it hard to pedal their way to their destination, whatsoever the distance. The electrification of the trike also helps the user navigate hilly roads in the city. The python recumbent trike also combats affordability and sustainability. The operational cost of a recumbent trike is very limited. The recumbent trike also has regenerative braking, which will assist in charging the trike partially. Assuming that the trike charging is not assisted by regenerative braking and is only getting charged by the wall, and the user is riding the trike for 5 Hours a day for the entire month, the operational cost for the trike is $10.56 a month at maximum based on our calculation for a 500W motor included in *Appendix A*. Whereas a monthly city bus pass costs $70.00 per adult and cab services in Kelowna charge $2.25 (CAD) per kilometre travelled. Since the recumbent trike is operated mechanically with electrical assistance it is the most eco-friendly option for the residents of Kelowna to rely on.

The reason for exploring a recumbent trike as our solution to combat transportation issues in Kelowna intensively and not any other possible ways is because, we believe that this method not only solves the three main components around transportation around the city (affordability, efficiency in terms of frequency and area coverage and sustainability) but also promotes safety, accessibility and healthier community. The entire purpose of our design is to make this an open-source design so that any person can build this trike with ease and proper instruction, hence promoting accessibility. Since it is a recumbent trike, it can also be used by people of various abilities and ages safely, hence addressing another pillar of accessibility and safety. Secondly, the operation of the trike involves the mechanical operation of the trike by pedalling, it promotes a healthy community.

4. Conclusion

In order to elaborate on the impact of the project on Kelowna residents, the future dealing with the environmental, social, and economical need for accessibility in the e-trikes must be showcased. The main purpose of the electrification of the trike is to allow the rider to get to their destination faster than a regular, manual road legal trike. Our trike is the most economically feasible form of available transportation. As it has the lowest operational costs behind purely pedal-based bikes and the lowest initial cost of purchase. The electrification of the trike also allows the creation of a safer motorized vehicle that acts as an environmentally safer option to regular gas vehicles, by emitting less carbon. Finally, the trike allows the driver to utilize an accessible method of improving fitness creating a positive social consideration for the audience.

Moving forward the next steps would be to start manufacturing the prototype of the trike and the app. Material such as steel, wheels and brakes have been acquired from scavenged bikes and Metal Supermarket. As the prototype design has been finished (Included in *Appendix A)*, the electrical team will start to source their parts and start assembling the control system so that it can be tested before placing it on the final version of the trike. The creation of our Skid App will be done simultaneously with the assembly of the control system to ensure that the hardware is communicating effectively with the software.

5. References

A. Barnes, G. (2022, November 24). *Transit riders in Kelowna community concerned about safety*. Revelstoke Review. Retrieved December 1, 2022, from https://www.revelstokereview.com/news/transit-riders-in-kelowna-community-concerned-about-safety/

B. *BC Transit Fares Kelowna*. BC Transit - Fares - Kelowna. (n.d.). Retrieved December 2, 2022, from https://www.bctransit.com/kelowna/fares

C. *Explaining your British Columbia Electricity & Natural Gas Rates*. EnergyRates.ca. (2018, August 15). Retrieved December 2, 2022, from https://energyrates.ca/british-columbia/explaining-your-british-columbia-electricity-natural-gas-rates/

D. Kelowna is now the fastest growing city in Canada. (2022, February 9). *West Investor*. Retrieved from https://www.westerninvestor.com/british-columbia/kelowna-is-now-the-fastest-growing-city-in-canada-5046595#:~:text=Kelowna%2C%20B.C.%20is%20officially%20the,40%20CMAs%20in%20the%20country.

E. *Razor® PR200 pocket rocket electric pocket bike parts*. Razor PR200 Pocket Rocket Electric Pocket Bike Parts - ElectricScooterParts.com. (n.d.). Retrieved December 2, 2022, from https://electricscooterparts.com/razorpocketbike.html

F. Sensiba, J. (2019, May 11). *A Better Route Planner & Other Open Source Projects Need Our Help*. CleanTechnica. Retrieved December 2, 2022, from https://cleantechnica.com/2019/05/11/abrp-other-open-source-projects-need-our-help/

G. Seymour, R. (2021, December 16). *No one at the wheel; driver Shortage Forces Kelowna Transit Cutback*. Daily Courier. Retrieved December 1, 2022, from https://www.kelownadailycourier.ca/news/article_675b0882-5eca-11ec-bf93-1f616b8d3ded.html

H. Theelectricbike. (2022, July 9). *E-bike laws in your province*. Ebike Canada. Retrieved December 1, 2022, from https://ebikecanada.com/e-bike-laws-in-canada/

I. *Vehicle Registration: Electric Bikes*. ICBC. (n.d.). Retrieved December 2, 2022, from https://www.icbc.com/vehicle-registration/specialty-vehicles/Low-powered-vehicles/Pages/Electric-bikes.aspx

Appendix A: Calculation of Operational Cost of Trike

Motor wattage used: 500 Watts
Number of hours bike used for per day (assumption): 5 Hours
Charge per kilowatts in British Columbia: $0.1408

$$Operation\ Cost\ = 500W\ \times \frac{1\ Kilowatt}{1000\ Watt} \times 5\ Hours\ \times\ 30\ Days\ \times \frac{\$0.1408}{1\ KWatt}\ =\ \$10.56\ per\ month$$

Appendix B: Final Design of Trike Prototype