June 13, 2021

Dr. William Craig Scratchley
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RE: ENSC 405/440 Requirements Specifications for Swivel

Dear Dr. Scratchley,

The following document was prepared by the team at Swivel for our capstone project in ENSC 405W and discusses the requirements specification for our company's product line of both a delegator, and an application interface. Our company seeks to trivialise the communication gap between bicycle owners and renters by allowing rentals to be made entirely autonomously through our rental network.Within this document the specific requirements for such a system will be outlined and described in full.

Swivel seeks to utilise the tens of millions of bikes that are across North America to create a truly automated bike rental platform. This platform will allow users to make payments to borrow bikes and rent out their own bikes for profit, all without ever having to communicate directly with each other. The integration of both a mobile application and our delegator will allow a user to find and approach any Swivel bicycle parked securely anywhere and rent it at the convenience of their smartphone.

To accomplish our goal, Swivel will be designing both a delegator and the application software to go alongside it. The requirements of both our delegator and application software will be discussed in this document.

Thank you for reviewing the requirements specification for our new products. If you have any further questions, comments or concerns regarding our company please feel free to contact our CCO Pierre Drego at pdrego@sfu.ca.

Sincerely,
Mehrad Akhavan-Kharazi

Chief Executive Officer
Swivel

Requirements Specification

Automated Bike Rental Platform

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Abstract

Swivel is an automated bike rental service that allows bike owners to conveniently and remotely rent out their bicycles. Swivel produces a delegator integrated with mobile application software to give the providing end user full confidence that their bicycle will not only be kept safe, but used by someone who will get to enjoy it just as much as they do. Swivel's delegator will interface with application servers over wireless communication to lock and unlock the bicycle for the correct current user. With this technology in place it will become easy to rent a bicycle anywhere for any particular purpose. This document clearly describes the complete set of requirements for Swivel's product line covering all pertinent areas of hardware, electronics, firmware and software while following standard engineering practices.

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1 | Introduction and Opening Analysis

Traditional biking rental services are not robust enough to respond to the needs of customers. Their services can only be offered at very specific locations under very specific circumstances such as business hours and non-negotiable rates. Dockable bike sharing serves as an upgrade, offering more flexibility. However, this service still suffers from the *first/last mile problem* in areas such as Greater Vancouver. In addition, their ability to scale is dependent on their ability to raise capital, comply with government regulations, and can only move as fast as their government permits get approved. Non-docking bike sharing platforms solve the Last Mile Problem at scale. However, "scale" often devolves into having millions of bikes littered on the streets. The figure below isn't a field of flowers. It's a field of abandoned bikes after most of the 120 bike sharing companies competing went out of business [1]. Bike rental platforms suffer from the same problems as dockable bike sharing services, but cause significantly less litter and wasteful production.

Figure 1: Abandoned Bikes

Facebook, the world's largest social media provider, doesn't create any content. The world's largest taxi firm, Uber, doesn’t own any vehicles. Airbnb, the world's largest home rental accommodation provider, owns no property. The retailer, Alibaba, carries no stock. These companies own computer networks which control the interface between the consumer and the goods and services which puts them at an incredibly valuable position with limited liabilities. An example of a market that has not had a company take full advantage of such a business model is the biking industry - creating a tremendous business opportunity.

The global bike and scooter rental market is projected to grow from 2.5 billion in 2019 to 10.1 billion USD at a CAGR of 18.9%. This gives us a total addressable market of over 2.5 billion dollars [2]. Swivel strives to utilise millions of existing bikes to create an automated rental network - creating a seamlessly convenient experience for the bike owners and renters. This service requires an interface and platform - allowing renters and bike owners to interact. In addition, to automate such a service, a delegation device is required such that we can remotely assign authority to the users to operate the bikes.

[1] *The Last Mile Problem refers to logistical processes from the nearest public transport stop to an origin ("first mile") or the other way around ("last mile").*

1.1 | Scope

The motivation for this document is to thoroughly explain the requirements for the automated bike rental interface. This includes a full description of the requirements for the delegator's hardware, software and firmware. In addition, we discuss the required engineering standards and requirements for safety and sustainability.

1.2 | Requirements Classification

Requirements are defined using the following format:
{**Requirement Tag**} {**Section ID**}.{**SubSection**}.{**Requirement ID**}.{**Design Stage**}

The requirement tag (two letters) is helpful for tracking the nature of the requirement. The following are valid requirement tags:

- High Level (**HL**)
- Hardware (**HW**)
- Software (**SW**)
- Firmware (**FW**)
- Safety & Sustainability (**SS**)
- Engineering Standards (**ES**)

The design stage identifies the approximate timeframe under which the requirement must be fulfilled:

- **C - Proof of Concept**
- **P - Prototype**
- **F - Final Product**

The section, subsection, and requirement IDs help link the requirements to their relation in the documented requirement specification.

2 | System Overview

The Swivel platform enables almost any bike to be transformed into a vehicle for automated bike rentals. A device called a delegator essentially acts as a lock which allows authorised users to access the bike. The primary functionality the delegator offers is a secure compartment that contains the key dedicated to a bike lock (provided by the bike's owner) with the ability to unlock itself, revealing the key for users that rent it out.

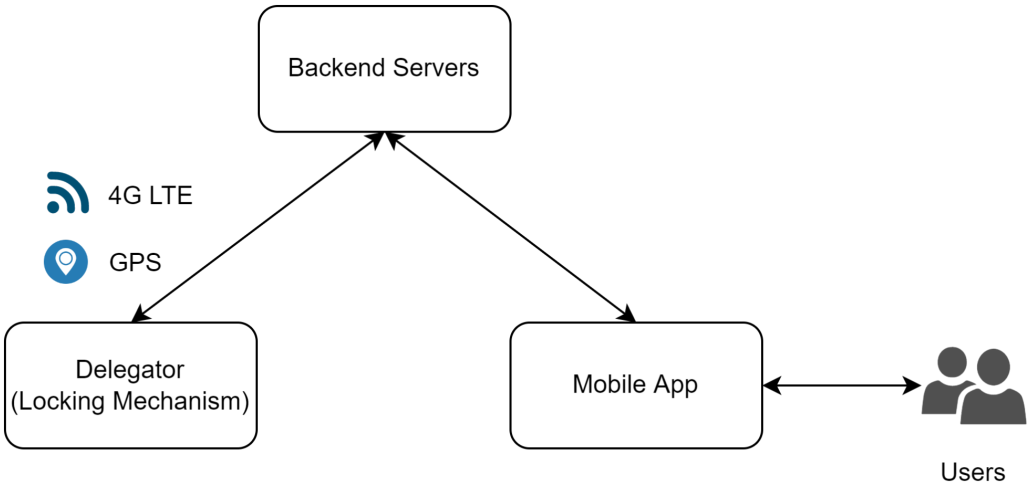

Figure 2: Swivel Platform High-Level System

The Swivel mobile platform and delegator achieve this functionality by focusing on three key technical areas (Figure 2) :

1. The mobile app allows users to rent out a bike and bike owners to add their bike to the platform.
2. The backend servers allow for secure communication between the delegator and the users.
3. The delegator provides the mechanical and electrical mechanisms for securing the bike to transfer access between users (owners and renters).

2.1 | Delegator System Overview

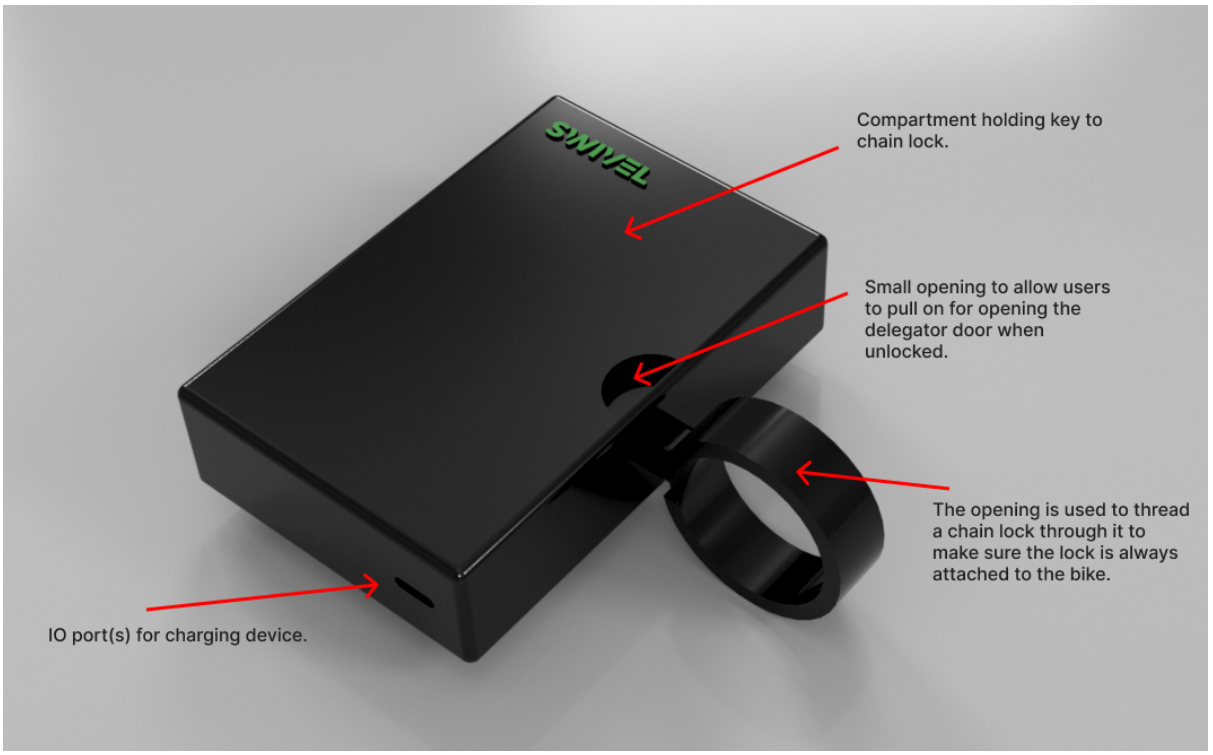

Figure 3: Swivel Delegator Design Concept
(Is subject to change, concept and demonstrational purposes only)

A conceptual demonstration of the delegator's anatomy, as seen in Figure 3,features a case which holds both the locking mechanism for the key compartment and the mainboard. The delegator contains a built-in secure mounting function which allows the bike owner to universally mount it onto their bike. The bike is officially delegated once the delegator is mounted to a part of the bike's frame. Locking is always performed physically, and requires no power. Unlocking requires the use of an internal solenoid which has its state triggered electrically by the mainboard.

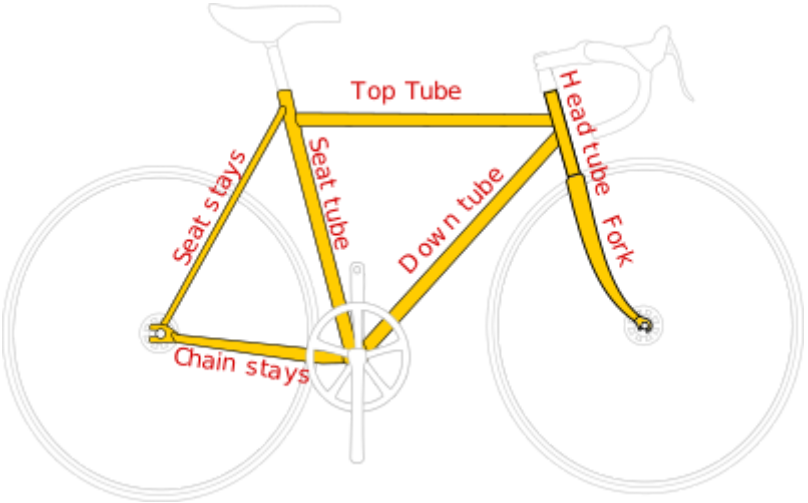

Figure 4: Bike Frame Structure [3]

The delegator mount is flexible enough to allow the delegator to mount to the top or down tube of the bike (Figure 4). A universal mounting function must be implemented so that the delegator is compatible with most common bikes.

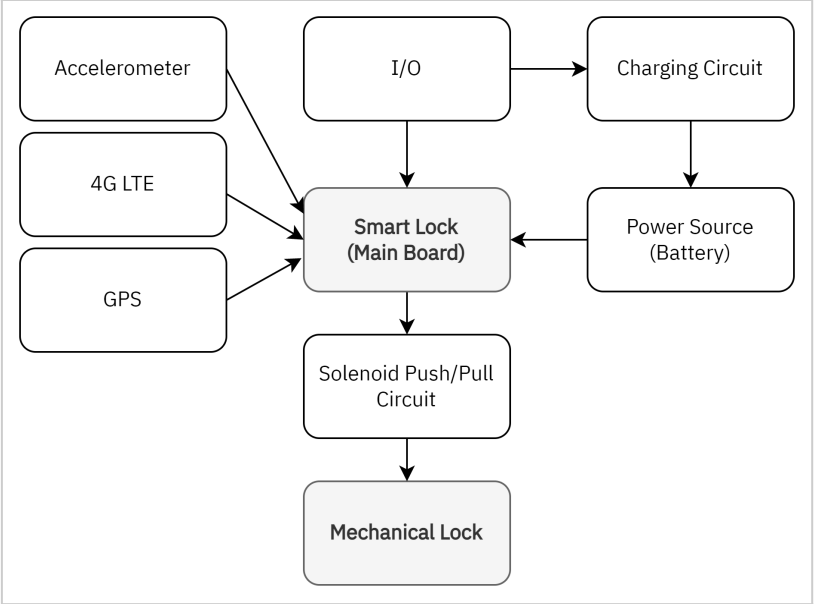

Figure 5: Swivel Smart-Lock High-Level System

Figure 5 shows a high-level overview of the mainboard system. The system is powered by an on-board powersource (typically a battery) to allow the device to operate in remote conditions. Charging is always done through the I/O ports accessible on the body of the delegator. Broadband communication over 4G LTE allows the delegator to receive instructions for unlocking the key compartment as well as to send telemetry data such as the location of the bike using the integrated GPS sensor. An integrated accelerometer is used to monitor for subtle bike movements to report potential theft. The key

compartment’s lock is unlocked electrically when the solenoid pushes on an internal mechanical component causing the locking mechanism to release.

2.2 | Backend Servers

Backend servers establish a secure form of communication between the users and the delegators. These servers handle any authentication and authorization needed to securely transfer access to the bike between users. These servers offer a platform which enables bike rentals to happen. The delegator is only able to unlock access to the key compartment upon authorization from the backend server.

2.2 | Mobile App

The mobile app provides users (owners and renters) a way to interact with each other securely. The bike owners indicate when their bike is available for rental and under which conditions. So long as the bike renter can fulfil these conditions (payment, drop-off location) the bike ownership is temporarily transferred through the use of the delegator which unblocks access to a key that the renter can use from this point onwards.

3 | High Level Requirements

The high level requirements indicate how the system should behave generally. They offer a glimpse into the functionality that the system must offer at a very high level.

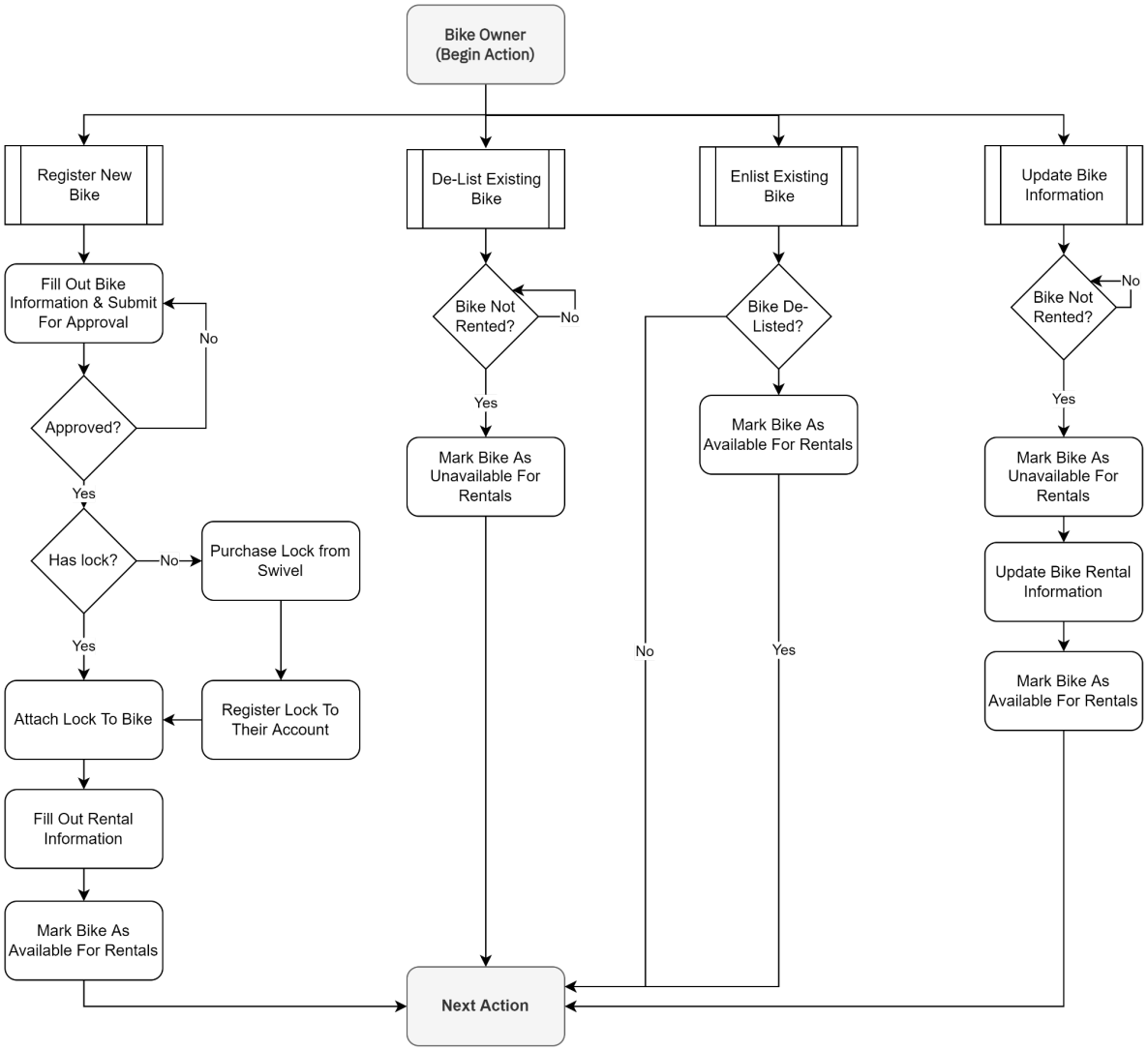

Figure 6: Bike Owner Expected Platform Interactions

Figure 6 demonstrates the actions a bike owner would expect to be able to perform through our platform. They need to be able to manage their bike listing, and update information as needed.

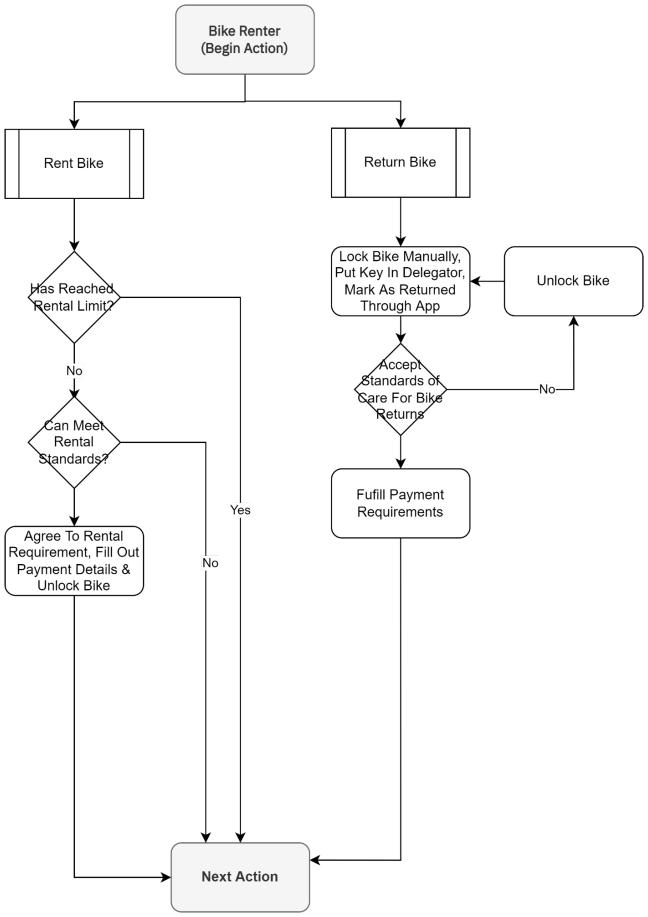

Figure 7: Bike Renter Expected Platform Interactions

As a user renting a bike, the platform should facilitate the full life-cycle of borrowing and returning the bike. Figure 7 helps demonstrate the actions a bike renter would expect to be able to take.

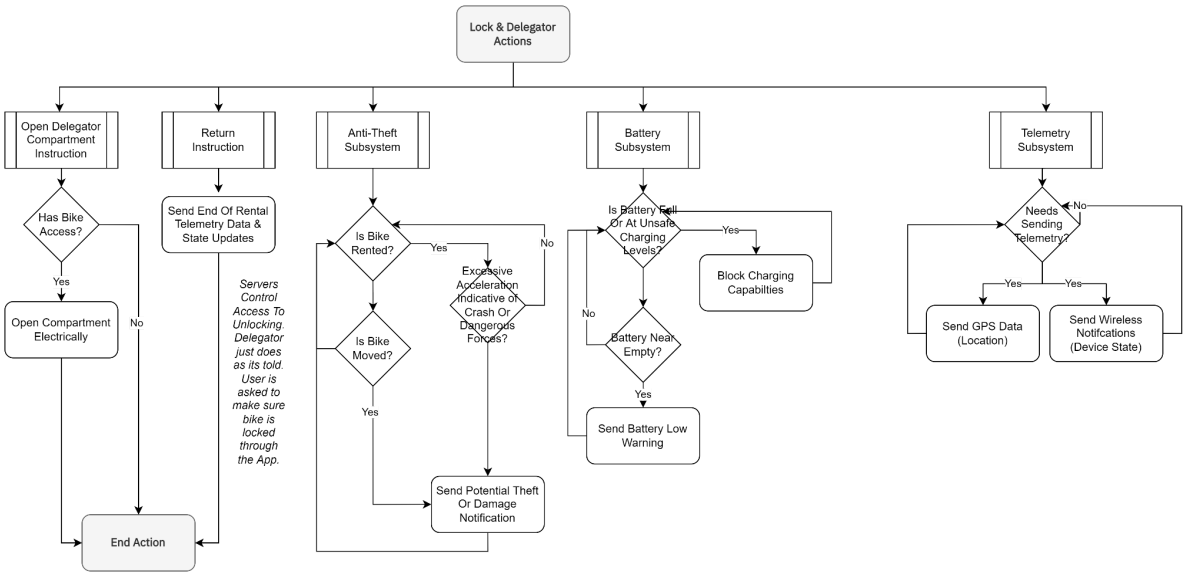

Figure 8: Lock & Delegator Expected Systems

Figure 8 demonstrates the key systems and subsystems the delegator and lock must have to serve the needs of the user. Telemetry data, power circuits, and anti-theft systems provide the necessary components to build out a system for automated bike rentals.

The following table summarises the general requirements that must be met by the product as a whole.

Requirement ID	Requirement Description
HL 3.0.1.PF	The system must allow bike owners to add their bikes onto the Swivel platform for rental.
HL 3.0.2.PF	The system must allow remote assignment of authority to the users to operate the bikes.
HL 3.0.3.CPF	The system must provide a way to unlock the bike remotely.
HL 3.0.4.CPF	The system must provide a way for renters to lock the bike they rented.
HL 3.0.5.PF	The delegator must be able to securely mount onto a common bike meant for adults.
HL 3.0.6.PF	The delegator and lock must be able to recharge internal batteries.
HL 3.0.7.PF	The delegator and lock must be able to operate for multiple days at a time without the need for recharging.
HL 3.0.8.PF	The delegator must be able to report suspicious bike movement to users based on accelerometer readings.
HL 3.0.9.CPF	The delegator must be able to report telemetry data such as device state, GPS location, and emergency notifications.

Table 1: High Level Design Requirements

4 | Hardware Requirements

The hardware requirements describe the mechanical functionality and design of the compartment lock and mount.

4.1 | Key Compartment Lock Mechanism

The following table defines the locking mechanism requirements for keeping the bike locked for owners and renters, and for unlocking when told to do so by the mainboard.

HW 4.1.0.CPF	The lock must be able to be locked by the common user by applying a small force on the locking mechanism.
HW 4.1.1.CPF	The lock must remain locked without the need for constant power.
HW 4.1.2.CPF	The lock must be able to lock mechanically without the need for power.
HW 4.1.3.CPF	The lock must only be unlocked electrically, and only when it is allowed by the mainboard.
HW 4.1.4.F	The lock should not break under reasonable stress or brute force applied by a human (300-500N) with no additional tools.
HW 4.1.5.F	The lock should not be forcefully openable when reasonable amounts of force are applied by a human (300-500N) with no additional tools.
HW 4.1.6.F	The lock mount must be able to withstand outdoors conditions (-20 to 50 °C, wet or dry climates) without unreasonable wear or failure of operation.
HW 4.1.7.PF	The lock must not interfere with regular bike usage and operation. All features of the bike must continue to work as per manufactured standards.
HW 4.1.8.PF	The cyclist should not feel physical discomfort due to the lock when operating the bicycle.
HW 4.1.9.PF	A common and reasonable bike operator must be able to mount the lock without the need for specialised tools that we cannot reasonably provide to the user.

Table 2: Key Compartment Lock Mechanism Requirements

4.2 | Delegator Mount

The delegator must be mounted onto the bicycle. The mount provides the delegator a place to sit so it does not dangle while the bike is in motion. The following table defines the mount requirements.

HW 4.2.0.PF	The Delegator must mount onto bicycle frame tube sizes of between 25mm - 47mm (average tube sizes for common bikes)[4].
HW 4.2.1.PF	The Delegator mount must keep the lock stationary during reasonable stress induced by the usage of the bike.
HW 4.2.2.F	The Delegator mount must be able to withstand outdoors conditions (-20 to 50 °C, wet or dry climates) without unreasonable wear or failure of operation.
HW 4.2.3.PF	A common and reasonable bike operator must be able to mount the Delegatorwithout the need for specialised tools that we cannot reasonably provide to the user.

Table 3: Delegator Mount Requirements

5 | Software Requirements

Swivel includes an application on the user's phone that will tell them where they can find a bike to rent, provide information about it and will unlock the bike for the user upon successful payment. An Arduino will work as the mainboard and thus the software will need to work appropriately with the Arduino.

5.1 | Application User Interaction

This table includes the requirements of the application software that an average user would interact with.

Requirement ID	Requirement Description
SW 5.1.1.CPF	Software must interact with a user's phone (Android/IOS).
SW 5.1.2.CPF	Software will provide the user with a GUI to interact with the application.
SW 5.1.3.PF	Users must be able to see a map with unused bike locations.

SW 5.1.4.CPF	Software allows a user's phone to unlock the bike lock
SW 5.1.5.F	Software will obtain payment from the user.
SW 5.1.6.PF	The app will allow a user to return a bike and verify that it has been returned.
SW 5.1.6.F	The app will have a user authentication system for keeping payment information secure and tied to one account.
SW 5.1.7.F	There will be a reasonable interface for a user to rent a bike, purchase/register lock, see information about the bike, track the time used and to end their ride.
SW 5.1.8.F	Owners will be able to set up their bikes, track it and remove it from the platform.

Table 4: Application Software User Interaction Requirements

5.2 | Firmware

This table includes the requirements of the firmware written to control the delegator.

Requirement ID	Requirement Description
FW 5.2.1.CPF	Firmware will receive requests from application software and will react and respond in turn.
FW 5.2.2.CPF	Firmware will make the mainboard go into sleep mode to preserve power, then periodically wake to communicate with the network.
FW 5.2.3.F	Firmware will detect damage to the lock through sensors and report it to users.
FW 5.2.4.PF	Firmware will encrypt and decrypt its communication to provide security for the lock.
FW 5.2.5.PF	Firmware will be able to check remaining battery life and report to the server if the battery is below a certain threshold.

FW 5.2.6.PF	Firmware will send an alert if the bike is moved when not in use and set off the alarm.
FW 5.2.7.CPF	Firmware will detect if the delegator lock is currently locked or not.

Table 5: Firmware Requirements

6 | Electrical Requirements

The mainboard, which is enclosed in the case of the delegator, contains the electrical components that power the Arduino. In addition to the power supply unit, components that allow for a renewable energy source to charge the power supply will be integrated into the device.

6.1 Power Supply Requirements

This table includes the requirements of the Power supply unit that is needed to provide power to our device.

Requirement ID	Requirement Description
HW 6.1.1.CPF	All of the system's components must be powered by the power supply unit.
HW 6.1.2.CPF	The Batteries should be able to recharge either by plugging them to a 120V AC wall plug using an adaptor or by using wind or solar renewable energy mounted on the bicycle.
HW 6.1.3.PF	The 5V power supply unit needs to be stepped up to 12 volts in order to power the Solenoid electric lock we are going to be using for the delegator.
HW 6.1.4.PF	The batteries should be able to last at least a week without recharging.
SS 6.1.5.PF	The unit should be waterproof and shockproof to prevent damage to the entire system in case of accidents on the bicycle or when raining.

HW 6.1.7.PF	The dimensions of the power unit should be small enough to be paired with the Delegator and the mainboard while not occupying an excessive amount of space that's disturbing to the user.
HW 6.1.7.CPF	Our device needs to have persistent memory storage to store any important data we may need.

Table 6: Power Supply Requirements

Our device has multiple components:

- The mainboard which includes:
    - RFID GPS tracker
    - GPRS module
    - The Delegator

On average, RFID GPS trackers use about 24-30 mA and a typical GPRS module uses about 0.25 Watts of power [5] [6]. Most basic solenoid electric locks are between 5 to 12 Volts and use about 0.6 to 1.5 Amps [7] [8].

Different components of our circuit will require different amounts of power. Since we are using a 5 Volt Lithium battery therefore, the only component that would possibly need 12 Volts to function is the solenoid lock. We would need to step up the voltage in order to power the Delegator. We could do this by building a step up converter circuit [9].

Because most of the components we are using use very low power, our batteries should be able to provide power for a considerably long time (at least a week) before they need to be charged again.

To charge our power supply unit we have considered 3 options.

1. Plugging the unit to a 120V AC wall plug using an adaptor
2. Using renewable energies to charge the unit which could be done in two ways
    a. Using a solar Panel that could be mounted at the back of the bicycle, where the carrier would be.
    b. Using a small wind turbine attached to the handle bar

In the case of using renewable energy sources we would also need to utilise a voltage regulator.

The device needs to include some sort of stable memory like an EPROM to store important data such as the private key we would need for encryption of data. We need the data to be stable so that important data does not get lost in case the device runs out of power and gets turned off.

For safety reasons, we would need to use a well insulated case with shock proof materials used inside the case to make our power supply unit both waterproof and shockproof. This is because our users might be using the bicycle under rainy conditions and they might have accidents where the device will undergo heavy impacts and we would like to prevent the user from getting electrocuted or taking damage from the explosion or combustion of the power supply upon impact.

7 | Safety and Sustainability

7.1 Sustainability Requirements

Swivel is dedicated to sustainability. As technology progresses, Swivel recognises that emphasising sustainability concerns is becoming increasingly important. The environment around us should not be compromised in the name of convenience. In response to these concerns, the following table outlines Swivel's commitment to sustainability.

Requirement ID	Requirement Description
SS 7.1.1.PF	The lifespan of the device should span at least 3 years to minimise waste.
SS 7.1.2.PF	The device can be powered by renewable energy.
SS 7.1.3.PF	The device must be designed to be repairable with readily available parts.
SS 7.1.4.PF	The device's wear and tear should not impede the usability of the device until it's minimum lifespan is reached.

Table 7: Sustainability Requirements

7.2 Safety Requirements

The safety of our users is of the utmost importance. Swivel is committed to ensuring that our technology does not compromise the safety of our users or those around them. It is important that our technology does not add risk of injury to an already risky activity. We take safety extremely seriously and have outlined our commitment to safety through the Safety Requirements table shown below.

Requirement ID	Requirement Description
SS 7.2.1.P	The device must not cause harmful interference with the mechanics of the bicycle.
SS 7.2.2.P	The exterior of the device must not contain sharp or jagged surfaces that would cause serious injury in the event of a bike accident.
SS 7.2.3.P	The device must not pose a risk of electrical shock even when wet.
SS 7.2.4.P	The battery must pose minimal risk of explosion even in extreme heat (up to 50 °C) or upon heavy impact.
SS 7.2.5.P	The Swivel application must encourage safe bike practices such as helmet wearing and obeying the rules of the road.

Table 8: Safety Requirements

7.3 Toxic Material Avoidance

It is crucial that Swivel avoids exposing the user and the environment to toxic materials. Swivel will avoid the use of high risk substances that pose immediate health or environmental complications and will take an active approach to minimising human exposure to toxic materials.

Requirement ID	Requirement Description
SS 7.3.1.P	Device must not expose the user to toxic materials that Health Canada deems toxic to humans [10].
SS 7.3.2.P	Device must not contain any toxic materials that Environment Canada lists as schedule 1 on their Toxic Substances list [11].

Table 9: Toxic Material Avoidance Requirements

8 | Engineering Standards

Swivel vows to adhere to the engineering standards outlined by The Government of Canada, Canadian Standards Association (CSA), and the International Electrotechnical Commission (IEC). The health and safety of our users depends on our close attention to the following standards outlined in the tables below.

8.1 Electrical Standards

Requirement ID	Requirement Description
ES 8.1.1.P	Swivel must abide by the Canadian electrical code, CSA C22.1 [12].
ES 8.1.2.P	CSA-C22.2 NO. 107.2-01 - Battery Chargers - Since the device will be rechargeable [13].
ES 8.1.3.P	CSA C22.2 NO. 0.23-15 - Battery-powered appliances - A requirement since this device will be powered by a battery [14].
ES 8.1.4.P	CSA E60730-2-12:19 - Automatic electrical controls - Our device will fall under these standards as it is considered an electrically controlled door lock [15].

Table 10: Electrical Engineering Standards

8.2 Environmental Standards

Requirement ID	Requirement Description
ES 8.2.1.P	CSA ISO 14001:16 - Environmental Management Systems [16].

Table 11: Environmental Engineering Standards

8.3 Wireless Standards

Requirement ID	Requirement Description
ES 8.3.1.P	Swivel must abide by Industry Canada’s RSS General Requirements of a Radio Apparatus [17].

Table 12: Wireless Engineering Standards

8.4 Software Standards

Requirement ID	Requirement Description
ES 8.4.1.P	CAN/CSA-ISO 9001-00 - Quality Management Systems - Since there will be a phone application [18]

Table 13: Software Engineering Standards

9 | Conclusion

The requirements specification for Swivel has been meticulously reported in this document to clearly specify a product that will forever change the biking rental space. The combination of a delegator and application software will allow renters and owners alike to participate in a new, more economical way to bike.

Swivel aims to change how people get around. In a world with ever increasing cost of transport, bicycling could be part of a greener and less expensive future for those willing to make the switch. Rather than mass producing thousands of bicycles to fill the streets, Swivel will utilise the already present resource of bicycles in people's hands to create a bike sharing network that could span continents.

To reach large goals the product has to be designed diligently, leaving no stone unturned. This document provides a clear road map for the design of Swivel's delegators and application, covering all aspects of hardware, software and electrical requirements to eventually produce the best product possible. Swivel's line of products will reach the proof-of-concept phase by August 2022 and the engineering prototype will be ready in December 2022.

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11 | Acceptance Test Plan

This acceptance test plan ensures that the basic functionalities that will be needed for the Swivel to reach completion are tested. The requirements include examples of the typical scenarios that the Swivel will be subject to, as well as some base requirements. The expected results are how the Swivel should behave under these scenarios.

Requirements	Expected Results
If a user attempts to forcefully open the Delegator, it should not open.	The Delegator will stay closed, if someone uses reasonable force to try and open it.
User attempts to open the lock using the phone application.	The lock should open once the user presses the appropriate button on the mobile application.
The delegator should have a mechanism to lock the bike key.	This device should house a mechanism to open and close the lock as needed.
User checks the location of a bike using the app.	The device and bike are located on a map, shown on the application, with decent accuracy.
Delegator is locked to a user.	The phone application should detect that the delegator is unavailable for rentals.
Delegator is open to receive rental requests.	The phone application should detect that the delegator is available for rentals.
The application should be accessible using either an Android or an iPhone.	The application should have equal functionality using either device.
The system is powered through a 5V Lithium rechargeable battery.	System runs as expected from a 5V power supply unit.
The Device will remain powered on for at least 24 hours on one charge.	The device will remain in low power mode, turning on components as needed.

Table 14: Acceptance Test Table