October 19, 2015

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
8888 University Drive
Burnaby, BC V5A 1S6

Re: ENSC 440W Functional Specification for QuickPost

Dear Dr. Rawicz:

The enclosed document is a functional specification for QuickPost, a product that will allow users to retrieve their mail effectively. Our goal is to design and implement a mailbox system that sends notifications to recipients through e-mail. Additionally, we hope to improve security and convenience of large package deliveries with a parcel container that is part of the QuickPost system. This container will use a locking mechanism which will allow recipients to collect their packages securely through the use of a key fob. We highly believe that our product will help users save time and relieve worries about stolen packages in communities.

The objective of the enclosed functional specification is to provide an overview and breakdown of the system, as well as hardware and physical requirements. Each breakdown will outline the system's functionality for the proof-of-concept and production versions of QuickPost. Additionally, the sustainability and safety of QuickPost, as well as any engineering standards that may apply to the system are examined.

Smart Post Solutions consists of five passionate, detail-oriented, and talented senior engineering students: Anmol Bhullar, Lestley Gabo, Jay Kim, Paola Pilaspilas and Jinhong Min. If you have any questions or concerns about our proposal, please feel free to contact me at 604-653-7204 or by e-mail at asbhulla@sfu.ca.

Sincerely,

Anmol Bhullar
President and CEO

Enclosure: *Functional Specification for QuickPost*

Functional Specification for QuickPost

Prepared for:

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Executive summary

According to [1], Canada Post performs door-to-door delivery for approximately 5 million addresses, which is only one-third of the total addresses served. The remaining recipients collect mail from "community, apartment or rural-lot line mailboxes" [1]. Due to the low number of door-to-door deliveries, Canada Post has pushed for the use of community mailboxes with their Five-point Action Plan [2]. As a result, approximately one million households have already converted to community mailbox delivery [2].

However, some communities have objected the change as accessibility issues arise with seniors. When Canada Post ended its door-to-door delivery service for 5,500 Windsor-Essex homes, Kingsville citizens voiced their opinions [3]:

"*From an accessibility standpoint, some of our seniors won't be able to reach the mailboxes.*
-Ford Queen, Kingsville deputy mayor

"*I'm unable to walk too far now because of my back and my hip…Therefore, it's an inconvenience, great inconvenience if I have to walk anywhere to pick up my mail.*"
-James Robinson, Kingsville resident

QuickPost aims to solve the preceding issues by sending notifications through e-mail to the mailbox owner when mail has arrived. In addition, the parcel container intends to provide convenience and security for all parties involved during the package delivery process. A summary of QuickPost's features is provided below in Table 1.

Table 1: Summary of QuickPost's features

Mailbox		
	Prototype	Final Product
Hardware	Arduino UNO R3 Sensor Kit Wi-Fi Shield PushButton LED	Camera Module
Software	Sensors movement within the mailbox, sends its data to Arduino and relays this information to the recipient using Wifi Shield	Sensors movement within the mailbox, sends its data to Arduino and takes a picture of the contents of the mailbox

Parcel Box		
	Prototype	Final Product
Hardware	Arduino UNO R3 Lock Mechanism Alarm System Wifi Shield	Keypad Camera Module Load Sensor
Software	Receives data from pushbutton, relays it to Arduino, activates the lock mechanism and the alarm. Connects to wifi shield to notify recipient	Sensors detect open parcel box and less weight, sends data to Arduino, activates camera module. Correct combination of passcode detected, alarm is off.

The following specification provides a list of QuickPost's hardware, physical, and safety requirements. Also, the functionalities are justified with the goal of providing convenience and security to the current mail/package delivery system. Lastly, sustainability considerations are outlined as QuickPost intends on following the cradle-to-cradle design approach.

Table of Contents

List of Figures

List of Tables

Glossary

802.11b/g/n	802.11 – IEEE standard for media access control and wireless local area network, b/g/n are different versions of the standard
Arduino	Commonly used prototyping platform, utilizes microcontroller
CSA	Canadian Standards Association, provides testing and certification for energy efficiency standards
IEEE	Institute of Electrical and Electronics Engineers, organization known for developing standards for computers and electronics
LAN	Local Area Network, interconnects computers in a limited way
LED	Light Emitting Diode, a diode that emits light when activated
NESC	National Electric Safety Code, United States standard for safe installation, operation, and maintenance of utility systems
PVC	Polyvinyl Chloride, a widely used synthetic plastic polymer
QP	QuickPost, mail/package notification system
WEP	Wired Equivalent Privacy, security protocol
WiFi	Wireless Fidelity, allows devices to connect wirelessly to the internet in a particular area
WLAN	Wireless Local Area Network, local area network that does not use Ethernet cables
WiFi Shield	A device that attaches on the Arduino, allows Arduino to connect to the internet using WiFi

1) Introduction

For most apartments and office buildings, mailboxes tend to be placed on the ground level while for some residential neighbourhoods, the mailboxes are placed at a designated but inconvenient location. In these cases, people tend to walk or drive to their mailboxes every few days to retrieve their mail. Unfortunately, receiving unwanted mail (such as fliers) are common occurrences and may frustrate recipients who spend their time and energy collecting their mail. Travelling to an empty mailbox is especially frustrating for seniors and people with disabilities as walking or driving are not easy tasks for them. Furthermore, there is the issue of missing a package delivery. If the recipient is not present for their delivery, the courier will either leave the package on the ground or notify the recipient of a pickup location for their package. The former presents a security issue while the latter presents an inefficient method of delivery (for both courier and the recipient).

Smart Post Solutions hopes to bring an end to the preceding issues with QuickPost. QuickPost aims to notify the receiver that mail has been placed in their mailbox. An additional task is to provide visual feedback by sending images of the mailbox contents to differentiate between junk and meaningful mail. The second component of QuickPost aims to provide a secure and hassle-free method of package delivery. With QuickPost's parcel container, couriers can drop packages off even if the recipient is not present. The container will remain locked until it is unlocked by the intended recipient. Additional security measures (e.g. alarm, camera, load sensors) are implemented in case anyone who is unauthorized attempts to open the container. A visualization of the QuickPost system is provided below in Figure 1.

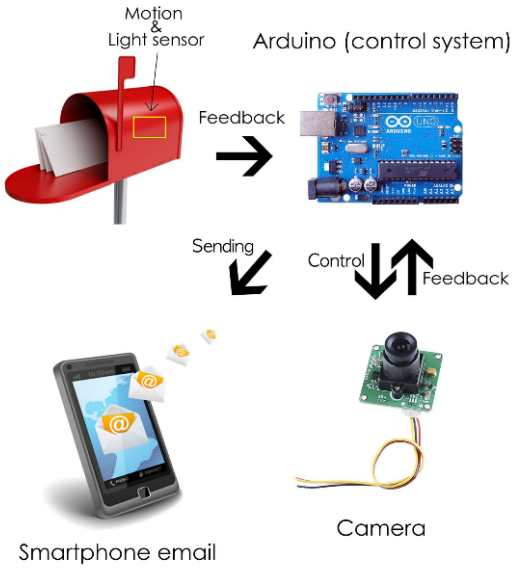

Figure 1: QuickPost system overview (images taken from *[4, 5, 6, 7]*)

a) Scope

The functional requirements of QuickPost are outlined in the subsequent sections. These requirements will be used to define the proof-of-concept and production versions of QuickPost. Additionally, members of Smart Post Solutions should refer to the functional requirements during the product design phase.

b) Intended Audience

The functional specification is intended for all members of Smart Post Solutions. Ideally, the listed functional requirements should be clearly seen in the resulting proof-of-concept device. Furthermore, the specification is intended towards Canada Post and courier service companies (e.g. UPS, DHL) in the assistance of implementing QuickPost throughout Canada.

c) Classification

The convention used to number and classify priority levels of each requirement is provided below:

[R#-X]

where # is the requirement number and X is specified as follows:

A - Highest Priority: Core/critical features of the system
B - Medium Priority: Necessary for the system to perform essential functions
C - Low Priority: Complement features/functions

Requirements of priority A and B will be considered for the proof-of-concept device, while priority C requirements shall be considered in later stages of the design phase.

2) System Overview

a) Top Level Design

QuickPost will have two components: a sensor device for the mailbox and a parcel container with incorporated security features. A high level diagram of the former component is provided below in Figure 2.

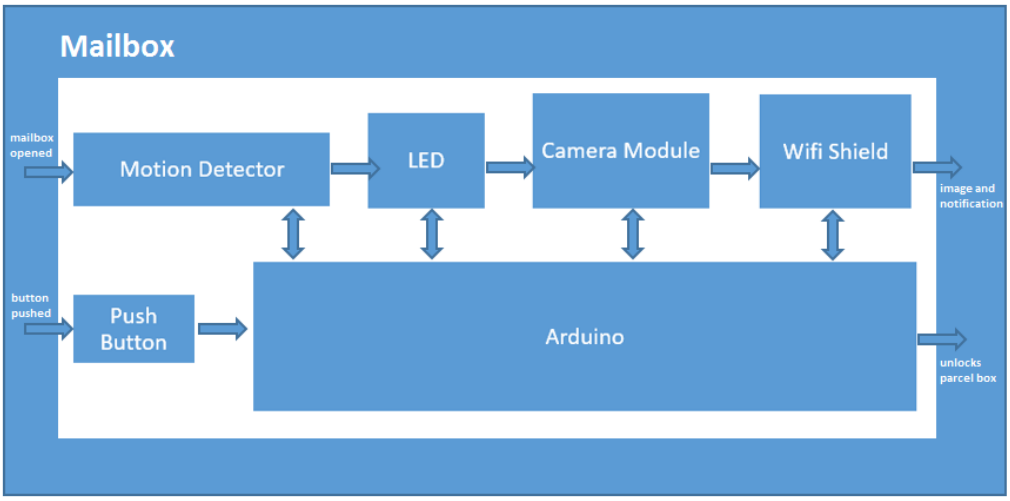

Figure 2: High-level block diagram of mailbox subsystem

The mailbox component of QuickPost will be attached on the inside ceiling of the mailbox. The proof-of-concept device will consist of a microcontroller (Arduino) that controls a camera module, motion detector, LEDs, WiFi shield, and a pushbutton. When the mailbox is opened, the LED lights will turn on, and an image of the contents of the mailbox is sent to the recipient via e-mail. A WiFi shield for the Arduino is necessary to connect to the internet and provide feedback to the receiver. Lastly, a pushbutton is used to control the solenoid lock of the parcel box. An overview of the parcel container subsystem is provided below in Figure 3.

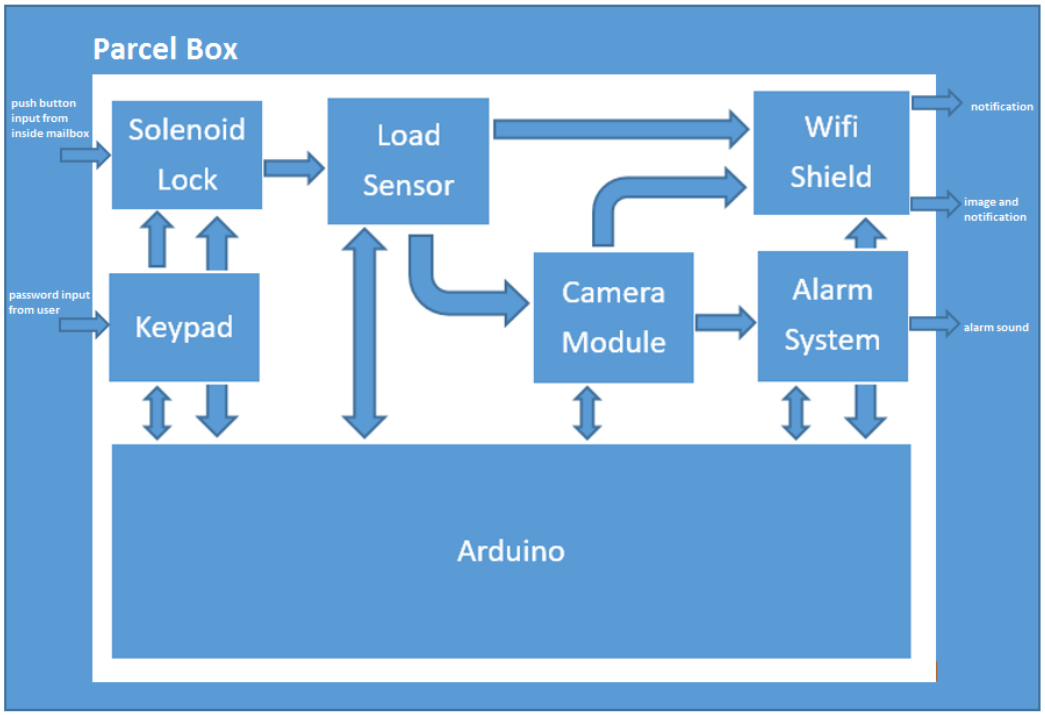

Figure 3: High-level block diagram of parcel container subsystem

Similarly, the proof-of-concept version of the parcel container utilizes an Arduino, camera module, and Wi-Fi shield. Additionally, load sensors, solenoid lock, keypad, and an alarm will be implemented. When the pushbutton from inside the mailbox is pressed, the solenoid lock will unlock the parcel container allowing the courier to place the package inside. As a security measure, the load sensor is placed on the bottom of the container to relegate the weight inside. As a result, the courier will only be able to place things inside the container but is unable to remove packages without setting off the alarm and camera. Furthermore, a security mechanism is created by the combined efforts of the solenoid lock, keypad, load sensor, camera, and alarm. Deactivating the security mechanism requires a password input using a keypad. If the security mechanism is not deactivated when the contents are taken out, the alarm is activated and an image of the unauthorized person(s) is sent to the receiver.

b) Functionality Justification

Functionality has been set up such that users can stay home and simply check their e-mail for QuickPost notifications. With QuickPost implemented, there will be no need to spend time or energy to travel to a mailbox for the sake of checking if mail has arrived. The camera module adds the benefit of seeing inside the mailbox and allows recipients to see what kind of mail has been received. As a result, users do not have to go to their mailbox to collect fliers if they do not want to.

The functionality of the security mechanism allows for a simple and convenient system for receiving package deliveries. Instead of driving to the post office to pick up a package, the courier can simply leave it inside the parcel box. Furthermore, the security mechanism should lower the incentive to steal as the chance of being caught in the act increases. In short, QuickPost's goal is to implement a mailbox system that sends notifications to recipients through e-mail and make large package deliveries convenient. The functionalities chosen all align with the goals of QuickPost.

3) System Requirements

a) General Requirements

[R1-A] The sensors shall detect movement in the mailbox
[R2-A] QP shall have LED indicating if the mailbox is open (ON) or not (OFF)
[R3-A] QP shall have internet connectivity
[R4-B] The camera module in the mailbox shall capture images of the mailbox contents when LED is ON
[R5-C] The retail price of the system is under $100
[R6-A] The load sensor shall detect the weight of the parcel box contents
[R7-A] A pushbutton on the mailbox component shall open the parcel box
[R8-A] A lock mechanism shall be installed for the recipient's parcel box

[R9-B] The camera module in the parcel box shall capture images of the box opener when security is enabled
[R10-A] Alarm should turn on when parcel box is opened and security is enabled
[R11-A] Alarm should turn on when load sensor detects less weight and security is enabled
[R12-A] Security is disabled when correct passcode is entered on the keypad

b) Environmental Requirements

[R13-A] QP shall operate in both indoors and outdoors environments
[R14-B] QP shall operate in various weather conditions
[R15-A] QP shall operate within WiFi connection range

c) Safety Requirements

[R16-A] Microcontroller and electronic components shall be enclosed securely to prevent loose components
[R17-A] Microcontroller and electronic components shall be dry at all times
[R18-A] The enclosure shall be designed in a way to not injure the user (e.g. cuts while taking mail out)

4) Hardware Requirements

i) Microcontroller Requirements

The proof-of-concept device will use an Arduino to control QuickPost's functionality. As mentioned, the Arduino coordinates the motion sensor, LED, camera, WiFi connectivity, and security mechanism. The enclosure shall be attached to the top of the mailbox to provide enough room for mail to be placed inside.

a) General Requirements

[R19-A] Microcontroller used may be an Arduino Uno or Arduino Mega
[R20-A] Microcontroller will receive data from the motion sensor
[R21-A] Microcontroller will receive data from the camera module
[R22-A] Microcontroller will send data to the user using WiFi

b) Physical Requirements

[R23-A] Microcontroller will be securely connected to an enclosure
[R24-A] Mailbox microcontroller will be secured on the top of the mailbox because of the enclosure
[R25-A] Parcel box microcontroller will be secured inside the wall of the parcel box

c) Electrical Requirements

[R26-A] Microcontroller will use an operating voltage of 5V
[R27-A] Microcontroller may use a 9V adapter

[R28-C] Microcontroller shall be powered with a Lithium-Ion or Nickel-metal Hydride battery

ii) Sensor Requirements

There are two sensors utilized by QuickPost. The motion sensor inside the mailbox is used to detect if the mailbox has opened, while the load sensor is used as part of the security mechanism.

a) General Requirements

[R29-A] The motion sensor will properly detect mail being placed inside
[R30-A] The load sensor will measure weight discrepancies inside the parcel box

b) Physical Requirements

[R31-A] The motion sensor will always sense the mailbox door regardless if mail is placed inside
[R32-A] The load sensor will be protected from dropped parcels

iii) LED Requirements

LED lights are used to brighten the inside of the mailbox. The electrical signals from the motion sensor shall turn the LEDs on. The quality of images captured by the camera may be proportional to the brightness of the LEDs.

a) General Requirements

[R33-B] The LEDs shall sufficiently brighten the inside of the mailbox
[R34-B] The LEDs turning on will send signals to the microcontroller to turn on the camera module
[R35-B] The LEDs will remain off when the motion sensor sends signals that the mailbox is closed

b) Physical Requirements

[R36-B] The LEDs will be positioned on the enclosure to maximize brightness

iv) Camera Module Requirements

The camera module is managed by the microcontroller and will take an image only when the LEDs are on. As a result, the captured images will be sufficiently clear to the recipient. Furthermore, the camera shall capture images when parcels are taken out without disabling the security feature. The camera is used on the parcel container as an extra layer of security.

a) General Requirements

[R37-B] The camera will have a maximum of 640x480 resolution
[R38-B] The camera will save the captured image into an SD card on the microcontroller
[R39-B] The mailbox camera will capture an image of the inside of the mailbox when LED light is on
[R40-B] The parcel box camera will capture an image of the box opener when the security system is on

b) Physical Requirements

[R41-B] The mailbox camera will be placed on the back of the enclosure to capture the whole mailbox
[R42-B] The mailbox camera will not obstruct the contents of the mailbox from coming in
[R43-B] The parcel box camera will not obstruct parcels from coming in
[R44-B] The parcel box camera will be facing the person opening the container

c) Electrical Requirements

[R45-B] The camera will use 2.5V-3.0V of power
[R46-B] The camera will be powered by the Arduino board

v) WiFi Requirements

A WiFi Shield will be used on both microcontrollers for QuickPost. The Wifi Shield enables the Arduino to connect wirelessly to the internet and send notifications to the user. The production version shall use a WiFi chipset to perform wireless communication.

a) General Requirements

[R47-A] The shield will support 802.11b/g, WEP/WPA/WPA2 encryption, TKIP, and AES
[R48-A] The shield will connect to a wireless router
[R49-A] The shield will automatically connect to previously known wireless networks
[R50-C] QuickPost shall support 802.11n/ac

b) Physical Requirements

[R51-A] The shield will be attached to the microcontroller

c) Electrical Requirements

[R52-A] The shield will operate at 5V

vi) Parcel Box Security Mechanism Requirements

The parcel box security mechanism consists of the solenoid lock, keypad, load sensor, camera module and alarm. Since solenoid locks require a relatively large amount of power to operate correctly, an external battery pack (higher than 12V) is needed. Furthermore, if the correct passcode has not been entered, the security system will remain enabled. If the load sensors weight data decreases while the security mechanism is enabled, the alarm shall turn on and an image is captured by the camera. The image and notification will then be sent to the recipient.

a) General Requirements

[R53-A] The load sensor will measure weight discrepancies inside the parcel box
[R54-A] The keypad will receive input from the user and send the data to the microcontroller
[R55-A] The keypad data is always wrong until the user inputs the correct data
[R56-A] The solenoid lock will unlock if the data from keypad is correct
[R57-A] The solenoid lock will unlock if the data from pushbutton is received
[R58-A] The camera will capture an image of the user when the security system is on and load sensor data decreases

[R59-A] The alarm will turn on when the security system is on and load sensor data decreases

b) Physical Requirements

[R60-A] The load sensor will be protected from dropped parcels
[R61-A] The keypad will be attached on the outside the parcel box
[R62-A] The solenoid lock will be attached at the inside hinge of the parcel box cover
[R63-A] The camera will not obstruct parcels from coming in
[R64-A] The camera will be facing the user and not inside the parcel box
[R65-A] The alarm will be secured inside the wall of the parcel box

c) Electrical Requirements

[R66-A] The solenoid lock will be powered by 12V of power
[R67-A] The solenoid lock will use its own external power
[R68-A] All security mechanism devices except the solenoid lock will be powered by the Arduino board

5) Documentation Requirements

Documentation provided with QuickPost will be used to guide the user with setting up QuickPost as well as understanding the product's abilities.

[R69-C] The user manual and the warranty documentation will be included in the product package
[R70-C] User documentation will include a detailed installation and assembly guide in case of parts replacement
[R71-C] User documentation will include a printed user manual that also includes general and technical support information, written in both English and French
[R72-C] The user manual shall be available to access on the company website
[R73-C] The contact information and the address of the company shall be labeled in the user manual
[R74-C] The user manual will be user friendly and written for audiences with minimal knowledge of microcontrollers and electronic components

6) Engineering Standards

Given that QuickPost contains electronic components and is able to communicate wirelessly, there are several engineering standards that QuickPost should comply with. For example, the microcontroller used in QuickPost should be certified such that the electromagnetic interference from the device is under the limit set by the Federal Communications Commission [8]. Furthermore, the microcontrollers used in QuickPost should have minimized risk of electromagnetic emissions [9]. Arduino boards, which are used in the proof-of-concept device, are both FCC and CE certified. The aforementioned certifications should be considered with high priority for the production device. Some other standards that QuickPost should comply with are:

1) CSA Electrical code regarding wiring and wire bending space requirements [10]
2) IEEE Standard of NESC with regards to safeguarding persons from hazards arising from installing, operating and maintenance [11]
3) IEEE Standard on Wireless LANs with focus on local and metropolitan area network standards [12]

7) Sustainability

The sustainability of QuickPost will be considered with a cradle-to-cradle design approach defined by the Cradle to Cradle Products Innovation Institute [13]. For the current design phase, two categories of the design approach (material health and reutilization) are examined for the proof-of-concept and production devices. The remaining categories (renewable energy, water management, and social responsibility) shall be explored when QuickPost's design has been developed further.

a) Proof-of-concept

Material health deals with the use of certain materials and chemicals during the manufacturing phase as well as the "use and end-of-use product phases" [13]. Ideally, the preassembled electronic components (e.g. sensors, solenoid lock) shall be carefully chosen such that they are free of harmful chemicals (as deemed by the Institute) [13]. Furthermore, the parcel container will most likely be structured with plywood and cardboard-like material, which should not contain any banned chemicals outlined in [13]. In addition, jumper wires (typically composed of tinned copper insulated with PVC) and lead solder used on the prototype board shall be carefully managed to avoid contact with the environment. However, the proof-of-concept device will likely spend limited in the environment as only testing/debugging QuickPost may take place outdoors.

The end-of-use product phase consists of reusing or recycling parts used to build the device. Plywood and cardboard used to structure the parcel container can be easily disposed at waste recycling facilities. Sensors, camera modules, and Arduino boards can be reused for other purposes or recycled for precious metal recovery. Additionally, lead solder can be disposed at electronic recycling facilities. Solenoid locks can be disassembled and recycled at the end of the lock's life cycle as they are generally composed of plastic and metal. Lastly, the alkaline batteries used to power the Arduinos can be recycled to prevent additional toxic heavy metals in landfills.

b) Production

For the production device, the Arduino boards will be replaced with PCBs designed specifically for QuickPost's functionalities. As Smart Post Solutions will not be creating the boards, it is up to the PCB manufacturer to focus on environmental considerations during fabrication. The chosen manufacturer should consider issues such as contaminated rinse water, hazardous air emissions, and effluent management [14]. Furthermore, the electronic components selected for the production device shall not be created from materials deemed hazardous by the RoHS

directive (or equivalent North American standards). The list of hazardous materials include lead, mercury, and cadmium, which cause harm to humans and environment [15]. Lastly, since couriers and recipients may inadvertently come in contact with the enclosure, the plastic (or metal) enclosure for the circuit board should also comply with the banned list of chemicals outlined in [13].

Similar to the proof-of-concept device, the production version of QuickPost should be recyclable/salvageable once the product has reached the end of its life cycle. Given the physical requirements, the production version of the parcel container will most likely be made of an iron or aluminum alloy. Hence, the container can be salvaged for other uses by metal recycling facilities. Also, the copper (as well as any precious metals used) from the PCBs, wires, and components could be recycled. Lastly, the batteries used in powering QuickPost can also be recycled; recycling processes exist for various types of batteries (including Lithium-Ion, Nickel-metal Hydride, and Nickel-Cadmium) to extract valuable metals that were used during production [16]. One thing to note is the recyclability of the various types of batteries; completely recycling lithium-ion batteries is possible but not economically viable for the recycler, while Nickel-metal Hydride batteries contain enough nickel to be economically viable [17].

8) Safety

Various cases need to be considered when attempting to make QuickPost as safe as possible towards users (e.g. couriers, recipients, setup technicians). Since users will come in close proximity to QuickPost, the device should be properly enclosed to prevent any circuit contact. Even if QuickPost operates at relatively low voltages, exposed PCB contacts is still a significant precaution. Furthermore, use cases of QuickPost will generally take place outdoors. Therefore, special care must be taken to prevent any unwanted circuit behavior due to temperature changes. For example, a comparison between three widely used types of batteries is provided below in Table 1.

Table 2: Temperature effects on battery performance (data taken from *[18]*)

Parameter	Nickel-Cadmium	Nickel-metal Hydride	Lithium-Ion
Operating Temperature	-30 to 60°C	-20 to 50°C	-10 to 50°C
Storage temperature (>90 days)	0 to 30°C	0 to 30°C	0 to 30°C
Loss of charge per month (stored at 25°C)	20%	30%	3%

Despite a wide range of operating temperature, most batteries tend to perform sub-optimally in extreme temperatures, which can be a concern if QuickPost is to be used throughout certain

areas of Canada [19]. Similarly, electronic components with wide operating temperatures must be chosen for desired functionality. Overheating components inside the metal parcel container due to summer temperatures is another possible safety concern.

Asides from safety concerns regarding circuit failures, security around neighbourhoods where QuickPost is used may also be an issue. Given the value of reclaiming metals inside electronic components, ICs, and PCBs, there may be increased incentive to break into mailboxes and steal devices placed inside. Additionally, theft may be more common around neighbourhoods that use cluster mailboxes as there will be numerous devices in a small area. Lastly, the parcel container could be stolen as the raw material used in building the container may be valuable.

9) Conclusion

In this functional specification document, Smart Post Solutions have outlined the functional requirements of the QuickPost's system. Hence, this document will help the team of Smart Post Solutions to focus on what is necessary and unnecessary to complete the 2 phases of the project: hardware and software development. Summarized below are the 2 major design features that are to be implemented:

Developing the hardware will build the basis for the notification mailing system where a microcontroller unit will at its center gathering information and relaying this information to its components (e.g. camera module, WiFi shield, LED, lock mechanism, alarm system)
Developing the software will be implemented for users to get information about their mail. This will use the hardware component WiFi shield which will provide internet access for the system to connect to the user through email

The functional requirements have been divided into 3 categories: System, Hardware and Documentation with their own subcategories. The requirements are prioritized in terms of their importance during the development phases. We have concluded that the ability for the user to receive notification via email and having security features for our parcel box is our number one priority. In contrast, we have made the implementation of a camera module in our system the lowest priority because it is not necessary for the user to see the image of the contents of their mail in order to know that they have mail in their mailbox.

Lastly, in conjunction with following the Engineering Standards referenced in this document, we are confident that we will deliver the final project in a safely manner to future users of QuickPost. At Smart Post Solutions, we firmly believe that following strict guidelines in development and prioritizing them accordingly will make our development go smoothly. Evidently, this functional specification document highlights that we are ready in tackling this project from making a functional and user friendly product from its conception.

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