October 19, 2015

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
Burnaby, British Columbia
V5A 1S6

**Re: ENSC 440W Functional Specification for *Tesigo*: Smart Cart**

Dear Dr. Rawicz:

The attached document from *FOYO Technology Inc.* describing the functional specification for *Tesigo: Smart Cart*. We are designing and implementing a smart shopping cart which is capable of following customers automatically and being controlled via mobile application. *Tesigo* aims to provide a wonderful and convenient shopping experience for shoppers including disabled.

The objective of Functional Specification for *Tesigo* is to provide a set of high-level functional requirements which breaks down into general, mechanical, hardware and software requirements. This document also includes system overview of *Tesigo*, sustainability and safety. Our team members will use this document as a guideline for designing, implementing and testing *Tesigo*.

*FOYO Technology Inc.* was founded by five innovative, creative, analytic and motivated engineering students: Worawee Janpongsri, Mengyao Li, Zheng Chang, Yizhang Xu and Jose Arboleda. If you have any questions or concerns about our proposal, please feel free to contact me by phone at (778) 895-9945 or by email at wjanpong@sfu.ca.

Sincerely,

Worawee Janpongsri

Worawee Janpongsri,
CEO
*FOYO Technology Inc.*

Enclosure: *Proposal for Tesigo*: Smart Cart

FOYO Technology


# Functional Specification for a Smart Cart

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## Executive Summary

Human body is not meant for carrying heavy loads since the more weight you lift or carry can lead to body injury [1]. To be specific, we tend to carry more weight while shopping. Shoppers everywhere suffer from fingers numbness, chest and back pain, which caused by lifting heavy loads for several hours during their shopping time. Furthermore, the pregnancies and disabled have more difficulties in carrying goods. *Tesigo*, a smart cart, is a product which *FOYO Technology Inc.* is developing to provide shoppers a convenient and comfortable shopping experience. *Tesigo* allows shoppers to operate in multiple modes. Different modes provide different convenient levels to different shoppers. First is manual mode, shoppers operate the cart by pushing along their ways. Remote mode helps shoppers to control *Tesigo* through the mobile application. Lastly, following mode is the most effective mode that can detect and follow specific person automatically.

The development cycle of *Tesigo* uses the waterfall methodology which makes the process easy to follow and manage [2]. This breaks down into five phases.

1) **Concept Exploration** –Team identifies idea and need for a product to formulate possible approaches to high level solution. We also determine feasibility, identifying and mitigating risks of *Tesigo.*
2) **Requirements Analysis** – Team gathers, specifies and analyzes the requirement as well as defining functionality and scope of the product.
3) **Hardware and Software Design** – Team designs how hardware and software will be structured and verifying that the design meets the requirements.
4) **Implementation** – Building the cart, programming a micro-processor, Kinect2 sensor and mobile application.
5) **Testing** – Testing modules (unit test), combinations of modules (integration test) and the whole system (system test).

This document will provide software as well as hardware functional requirements with their sub categories. Our team will follow these functional specifications as the guidelines in developing *Tesigo* for the best solution.

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# Glossary

| | |
|---|---|
| App | Application; software designed to run on electronic devices |
| ABS/PP | Acrylonitrile Butadiene Styrene; material of plastic |
| Android | Mobile operating system currently developed by Google and designed primarily for touchscreen mobile devices |
| CAD | Canadian Dollar |
| CSA | Canadian Standards Association |
| DC | Direct Current |
| GPIO | General-purpose input/output; generic pin on an integrated circuit |
| ISO | International Standards Organization |
| KG | Kilograms |
| Km/h | Kilometer per hour |
| LED | Light Emitting Diode |
| M | Meter |
| OS | Operating System; system software that manages hardware and software resources and provides common services for programs |
| PCB | Printed Circuit Board; a self-contained module of interconnected electronic components found in devices ranging from common beepers, or pagers, and radios to sophisticated radar and computer system |

# 1. Introduction

*Tesigo* is an auto-moving robot, which is designed for carrying goods. It can be applied in many areas such as shopping mall, airport, and hospital. *Tesigo* can target a host, and follow the host automatically. So far, there is no such kind of robot working in the market, and we believe both companies and customers will be satisfied with this design. Users can easily control *Tesigo* by using our mobile App. Our aim is to release users' hands and give them an easier life.

## 1.1 Scope

This document describes the functional requirements of *Tesigo* by *FOYO Technology Inc.* The requirements are discussed later on in this document.

## 1.2 Intended Audience

The functional specification is intended for all staffs in *FOYO Technology Inc*. These functional requirements will be the standards and descriptions when engineers design *Tesigo*. Similarly, testing will also be based on this document, since these requirements represent the overall performance of *Tesigo*. Furthermore, this document will also be the guidance of designed specification document.

## 1.3 Classification

Throughout this document, the following convention shall be applied to symbolize functional requirements:

**[Rn - P]: A functional requirement.**

**R** represents the requirements for *Tesigo*, **n** represents the functional requirement number, and **P** represents the priority of the functional requirements, which specified by three levels below:

A. The requirement applies to the proof-of-concept system only.
B. The requirement applies to both the proof-of-concept system and the final production system.
C. The requirement applies to the final production system only.

## 2. System Overview

Our system includes four major parts: tracking system, mechanical system, microcontroller and user interface system.

*Tesigo* has three operating modes:

- Follow – The cart follows the user automatically with its dynamic and tracking systems.
- Manual – The power of the cart is off, and user uses the cart manually.
- Remote – The tracking system of the cart is off, and user use App on the cell phone to control the cart.

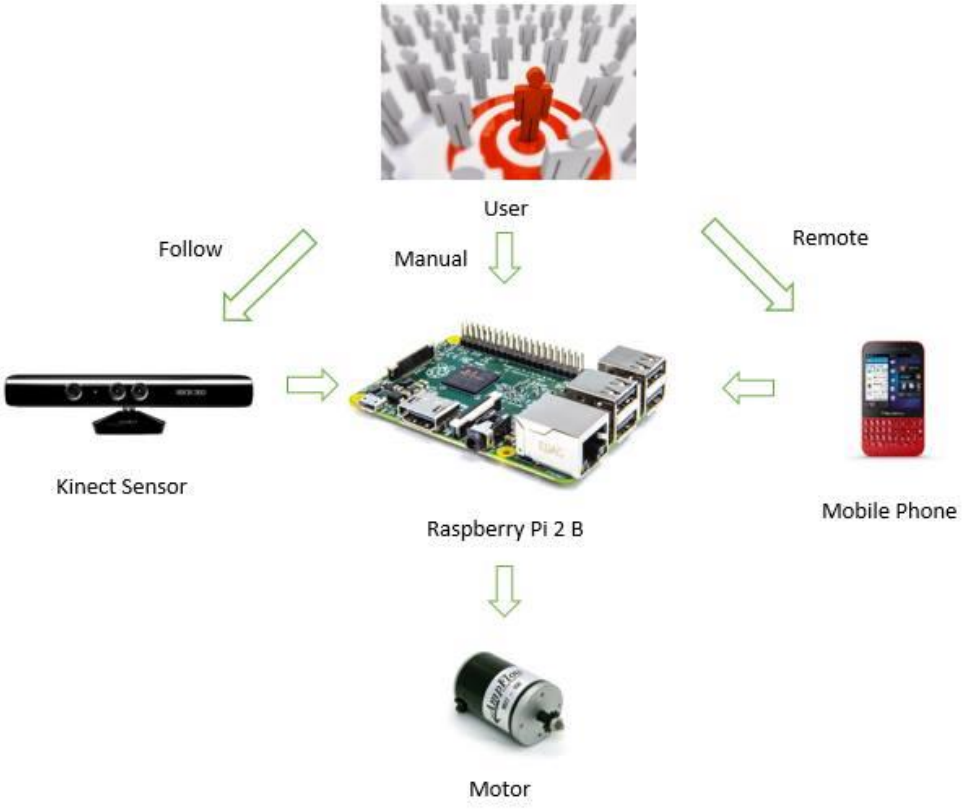


Figure 1: Basic Concept of *Tesigo* [8] [9] [10] [11] [12]

To obtain these functions, *Tesigo* uses three main systems: mechanical system, tracking system and user interface system. The tracking system utilizes Kinect2 Sensor to recognize and track the

user. Receiving the feedback from the sensor, the microprocessor (Raspberry Pi) will analyze the situations and send appropriate instructions to the mechanical system. After the motor driver receives the instructions, it controls the motor to make corresponding movement of the cart. Furthermore, the user interface system allows user to control *Tesigo* via the mobile application in the "Remote mode". In *TesigoApp* (mobile application), there are forward, backward, pause, turn left and turn right buttons, which allow the user to easily control the movement of the cart. The user is also able to switch among the modes in *TesigoApp*.

The basic description of the operation path is shown in Figure 2.

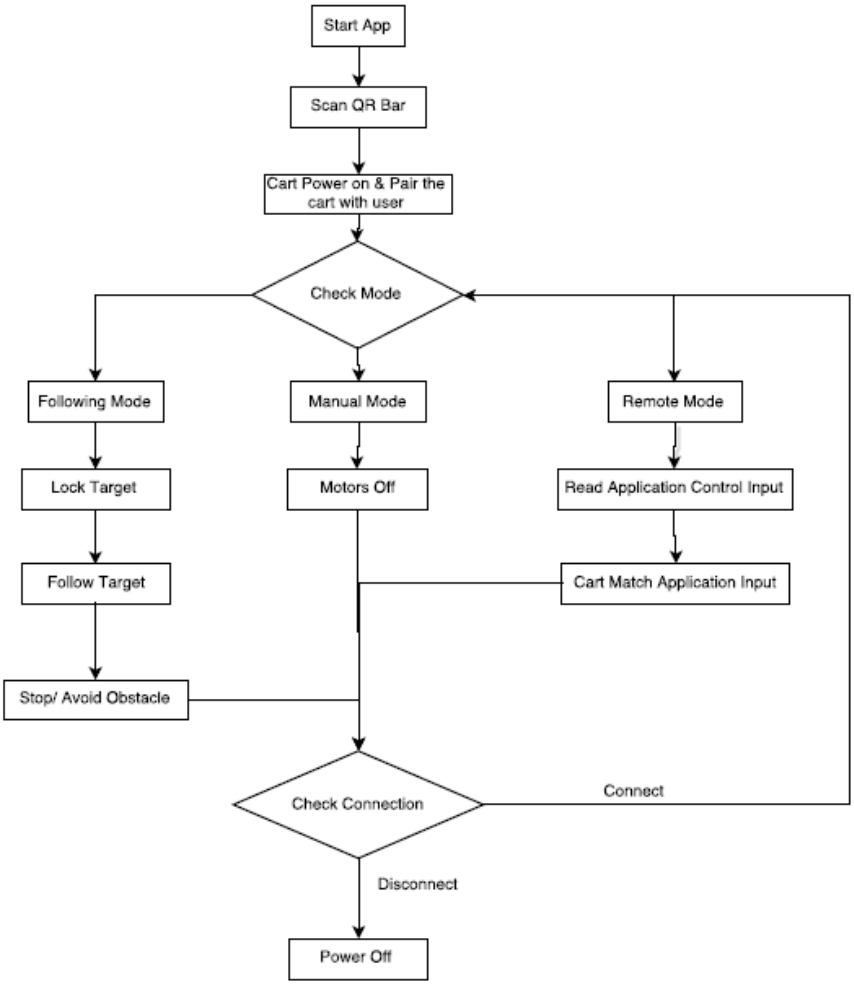


Figure 2: Basic Description of the Operation Path

### 2.1 General Requirements

[R2.1.0 - B] *Tesigo* is designed to be used indoor.

[R2.1.1 - A] The final price of *Tesigo* should not exceed CAD800.

[R2.1.2 - C] The mobile application of *Tesigo* will be free download.

[R2.1.3 - B] Each *Tesigo* has unique ID.

[R2.1.4 - C] The mobile application is easy to use by all customers.

### 2.2 User Interface Requirements

[R2.2.0 - A] There is a button on the cart to turn on all electrical components.

[R2.2.1 - A] There is a button on the cart to turn off all electrical components.

[R2.2.2 - B] Customer is able to use application to control *Tesigo* in remote mode.

[R2.2.3 - A] The application is able to show the battery status.

[R2.2.4 - C] A LED indicator is on when the battery level below 20%.

### 2.3 Physical Requirements

[R2.3.0 - A] The weight of *Tesigo* shall not exceed 11KG.

[R2.3.1 - A] *Tesigo* is able to handle the load capacity of 20KG.

[R2.3.2 - A] *Tesigo* shall not exceed 90x75x45 (cm) in dimension.

### 2.4 Electrical Requirements

[R2.4.0 - C] The battery of the cart shall be rechargeable.

[R2.4.1 - B] All electrical components of the cart shall be replaceable.

[R2.4.2 - C] A 12V battery shall be able to power all electrical components of the cart.

[R2.4.3 - C] The battery of the cart shall be able to complete recharged in 5 hours.

### 2.5 Standards

[R2.5.0 - C] All system shall conform to CSA Z462 standards for workplace electrical safety. [3]

[R2.5.1 - C] All systems shall conform to CSA Z463 standards for maintenance of electrical systems. [4]

[R2.5.2 - C] All electronic components shall conform to CAN/C22.2 NO.60335-1.11 for safety of electrical appliances for household and similar purposes. [5]

[R2.5.3 - C] All electronic components shall conform to ISO/TC 22/SC 3 for electrical and electronic equipment. [6]

[R2.5.4 - C] The motors shall conform to C22.2 NO.100-14 for motors and generators. [7]

## 3. Mechanical System

The mechanical system of *Tesigo* includes two DC motors which are powered by 12V battery. These motors will dominate the movement, steering and braking of the cart. In the "Follow mode", the speed of the cart will depend on the distance between the user and the cart and the maximum speed is 0.6 m/s. The performance of our motor is shown in Figure 3.

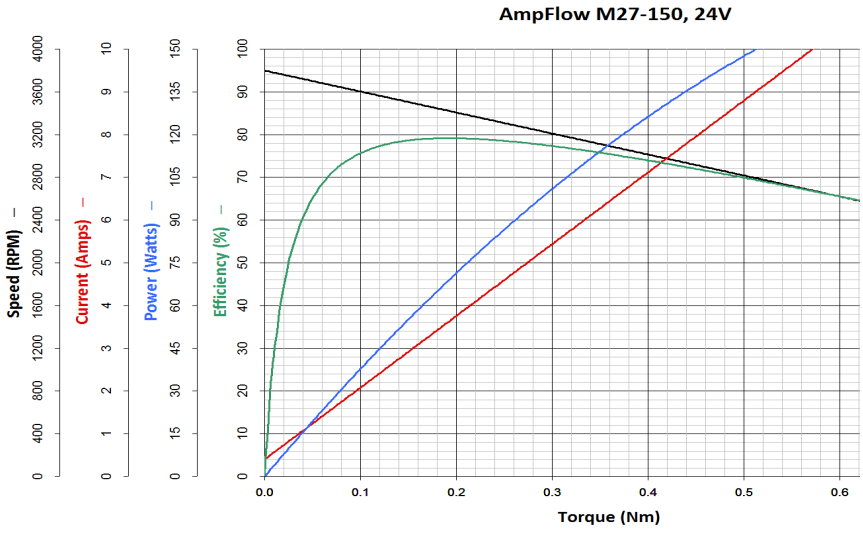


Figure 3: Graph of AmpFlow M27-150 Motor Performance [23]

### 3.1 General Requirements

[R3.1.0 - B] *Tesigo* is able to move both forward and backward direction.

[R3.1.1 - C] *Tesigo* can be used for the different speed of the two front wheels to steer.

[R3.1.2 - B] *Tesigo* shall have stable movement with/without the load.

### 3.2 Physical Requirements

[R3.2.0 - A] The weight of whole mechanical system should not exceed 10KG.

[R3.2.1 - B] The motors of the cart should be easy to remove and install.

### 3.3 Electrical Requirements

[R3.3.0 - C] The DC motors should be operated at 12Volts.

[R3.3.1 - C] To move the cart with the load of 30KG requires minimum current of 5Amps.

### 3.4 Performance Requirements

[R3.4.0 - C] *Tesigo* shall be able to take less than 0.5 seconds to reach the completed stop.

[R3.4.1 - C] The motors of the cart shall have enough power to move *Tesigo* with a load of 30 kg at a speed of 0.6 m/s.

[R3.4.2 - C] The distance between *Tesigo* and user is less than 0.5m.

## 4. Hardware Requirements

[R4.1.0 - C] The Cart's battery is rechargeable.

[R4.1.1 - C] The microprocessor, Kinect2 and motors are powered by the same battery.

[R4.1.2 - B] The microprocessor is able to receive data from Kinect2 sensor.

[R4.1.3 - B] The microprocessor is able to control the VHN5019 Motor Controller IC.

[R4.1.4 - C] The Motor Controller shall have heat sink and fan.

[R4.1.5 - B] The Motor Controller is operated from 5.5 – 24 Volts with a 12 Amps (30Amps peak).

[R4.1.6 - C] Make our own microprocessor to process image and control cart.

[R4.1.7 - C] All the electronic parts should remain functional between ranges of temperature of -10℃ and 50℃.

[R4.1.8 - C] All electronic parts are removable, easy to test and replace.

# 5. Software Requirements

Software of *Tesigo* comprises mobile application and Kinect2 sensor to interact with microprocessor.

### 5.1 Mobile Application Requirements

Mobile Application is the interface between user and *Tesigo* when user chooses to operate *Tesigo* in remote mode.

[R5.1.1 - C] The application allows users to login into their account.

[R5.1.2 - B] The application allows users to input *Tesigo* ID.

[R5.1.3 - C] The application checks whether a particular *Tesigo* is already in-use.

[R5.1.4 - C] The application rejects user to control a particular *Tesigo* if it is already in-use.

[R5.1.5 - C] The application allows user to a particular *Tesigo* if it is not in-use.

[R5.1.6 - B] The application allows user to start controlling *Tesigo.*

[R5.1.7 - B] The application allows user to switch the modes of *Tesigo.*

[R5.1.8 - B] The application allows user to control *Tesigo* in forward direction.

[R5.1.9 - B] The application allows user to control *Tesigo* in backward direction.

[R5.1.10 - B] The application allows user to control *Tesigo* to the left.

[R5.1.11 - B] The application allows user to control *Tesigo* to the right.

[R5.1.12 - B] The application allows user to stop/pause *Tesigo*.

[R5.1.13 - B] The application sends signals to micro-processor to turn GPIOs on/off.

[R5.1.14 - B] The application provides the user-manual.

[R5.1.15 - B] The application provides information about *FOYO Technology Inc.*

### 5.2 Kinect2 Requirements

[R5.2.1 - A] Kinect2 selects the first person when it sees as its targeted user.

[R5.2.2 - A] Kinect2 is able to keep track of the body user.

[R5.2.3 - B] Kinect2 is able to differentiate between the targeted body user and other objects (people) that may encounter in the way.

[R5.2.4 - B] Kinect2 sends information (data) to the microprocessor about the user's location.

[R5.2.5 - B] Kinect2 sensor provides the horizontal motion of the targeted user with respect to the current position of the cart (x-coordinates).

[R5.2.6 - B] Kinect2 sensor provides distance between the cart and the user (y- coordinates) using the depth sensor built-in.

[R5.2.5 - A] Kinect2 sends a signal to the microprocessor in case of losing track of the user.

[R5.2.6 - C] Kinect2 is able to target a user every time that the system is restarted.

[R5.2.7 - A] Kinect2 is able to target the body between distances of 0.8 to 4 meters away from the cart.

[R5.2.8 - B] Kinect2 keeps track of the user in environments with high or low light levels using the built-in infrared sensor.

# 6. Sustainability & Safety

**Sustainability**

At *FOYO Technology Inc.*, we designed *Tesigo* based on "Cradle and cradle" design concept [13]. This means, there is no such a thing as waste. *Tesigo* is environment friendly and most parts of *Tesigo* are reusable and recyclable.

The table 1 shows materials that are recyclable. According to PP production and recycling figures provided by American Chemistry Council [14], PP is one of the least recycled post-consumer plastics. In order to make our product more environmental friendly, we may change the material of wheels from ABS/PP to alloy in the future design and production phase.

The components, breakdown of each component's materials and the methods of disposal are shown in Table 1.

| Components | Materials | Method of Disposal |
|---|---|---|
| Cart Frame and Screw | Alloy | Recyclable [14] |
| Wheels, Tires, Wire Enclosures and Belts | ABS/PP, Rubber | Recyclable [15], [16] |
| Support plate, basket | Wood | Recyclable [17] |
| Battery | Lead, Sulphuric Acid | Recyclable [18] |
| Wires | Copper | Recyclable [19] |
| Board, Sensor and Resistors | PCBs, Silicon | Recyclable [20] |

Table 1: Material Consideration

**Safety**

*Tesigo* has considered as a safety product. When the follow mode is on, the tracking system of *Tesigo* can detect and track the individual person. *Tesigo* can detect obstacles ahead and brake to avoid collisions. If user uses the remote mode, *Tesigo* can be easily controlled by our *TesigoApp.*

In addition, *Tesigo* is in closed contact to the user, the components we used to build our product are safely contained to avoid causing any damages to the user or the system. There is no any components contained harmful or poisonous chemicals. In order to avoid any accidents to the user, the placement of the wiring, PCBs and other pieces on the support plate are carefully thought out and cleared up.

# 7. Conclusion

The functional requirements of *Tesigo* provide a comprehensive set of functionalities that will act as the guidance for our team to follow in the design and implementation phase of the project. The system design is divided into three major sections: hardware, mechanical and software sections; in each section we have given the priority to the basic functions which will allow us to deliver a functional proof-of-concepts model. Moreover, the extra features, which have a lower priority, will be implemented depending on the developing of the basic functions. The expected completion of the project is mid-November.

# Reference

[1] University Health Services Tang Center @ Berkeley, “Safe Lifting Tips,” [Online]. Available: http://uhs.berkeley.edu/facstaff/ergonomics/lifting/safelifting.shtml

[2] Wikipedia, “Waterfall model,” [Online]. Available: https://en.wikipedia.org/wiki/Waterfall_model

[3] CSA for Workplace Electrical Safety. (2015). Z452. Available: http://shop.csa.ca/en/canada/landing-pages/z462-workplace-electricalsafety/page/z462?source=Topsellers_Bestsellers. [Accessed October 17, 2015].

[4] CSA for Maintenance of Electrical System. (2012). Z463. Available: http://shop.csa.ca/content/ebiz/shopcsa/resources/documents/Z463WhitePaper.pdf. [Accessed October 17, 2015].

[5] CSA for Safety of household and similar appliances – Part 1: General Requirements. (2011) CSA-C22.2 NO.60335-1.11. Available: http://shop.csa.ca/en/canada/appliances/cancsa-c222-no-60335-111/invt/27023152011. [Accessed October 17, 2015].

[6] ISO for Electrical and electronic equipment. ISO/TC 22/SC 3. Available http://www.iso.org/iso/home/standards_development/list_of_iso_technical_committees/iso_technical_committee.htm?commid=46752. [Accessed October 17, 2015].

[7] CSA for Motors and Generators. (2014). C22.2 NO.100-14. Available: http://shop.csa.ca/en/canada/general-standards/c222-no-100-14/invt/27020952014[Accessed October 17, 2015]

[8] Raspberry Pi, 'Raspberry Pi 2 on sale now at $35 - Raspberry Pi', 2015. [Online]. Available: https://www.raspberrypi.org/blog/raspberry-pi-2-on-sale/. [Accessed: October 18, 2015].

[9] Ampflow.com, 'AmpFlow Standard Motors', 2015. [Online]. Available: http://www.ampflow.com/standard_motors.htm. [Accessed: October 18, 2015].

[10] Msdn.microsoft.com, 'Kinect Sensor', 2015. [Online]. Available: https://msdn.microsoft.com/en-us/library/hh438998.aspx. [Accessed: October 18, 2015].

[11] Minutemanburnaby.com, 'Direct Mail & Unaddressed Mail «Burnaby Printer – Minuteman Press Burnaby', 2015. [Online]. Available: http://minutemanburnaby.com/mail-marketing/. [Accessed: October 18, 2015].

[12] Wallpaperswide.com, 'Android Logo HD desktop wallpaper : Widescreen : High Definition : Dual Monitor', 2015. [Online]. Available: http://wallpaperswide.com/android_logo-wallpapers.html. [Accessed: October 18, 2015].

[13] William McDonough, Michael Braungart, Cradle to Cradle: Remaking the Way We Make Things, Farrar, Straus and Giroux, 2002.

[14] Newport Metal Recycling. Alloy Recycling. [Online]. Available: http://www.nmrscrap.com/alloy-recycling.html [Accessed October 16, 2015].

[15] Plastics Division of the American Chemistry Council, Association of Postconsumer Plastic Recyclers, "2010 UNITED STATES NATIONAL POSTCONSUMER," 2010.

[16] R. Sutton, "Tire Stewardship BC Annual Report to the Director," Tire Stewardship BC , Victoria, BC , 2014.

[17] B. C. Hall, "CITY SERVICES," 2015. [Online]. Available: https://www.burnaby.ca/City-Services/Garbage---Recycling/Organics-and-Clean-Wood-Disposal-Bans.html

[18] Copper Development Association Inc. (2015). Recycling of Copper. [Online]. Available: http://www.copper.org/environment/lifecycle/ukrecyc.html.

[19] Environment, Health and Safety Online. (Mar 3, 2014). Battery Disposal Guide for Households - Where to Safely Recycle Used Batteries. [Online]. Available: http://www.ehso.com/ehshome/batteries.php#BatteryFacts. [Accessed October 17, 2015].

[20] Environment, Health and Safety Online. (Mar 3, 2014). Battery Disposal Guide for Households - Where to Safely Recycle Used Batteries. [Online]. Available: http://www.ehso.com/ehshome/batteries.php#BatteryFacts. [Accessed October 17, 2015].

[21] Copper Development Association Inc. (2015). Recycling of Copper. [Online]. Available: http://www.copper.org/environment/lifecycle/ukrecyc.html. [Accessed October 17, 2015].

[22] EDN Network. (Dec 13, 2013). PCB materials: Recycle, reuse, dispose? [Online]. Available: http://www.edn.com/electronics-blogs/all-aboard-/4426020/PCB-materials--Recycle--reuse--dispose-. [Accessed October 17, 2015]

[23] Ampflow.com, 2015. [Online]. Available: http://www.ampflow.com/M27-150_Chart.gif. [Accessed: October 19, 2015].