Feb 12th, 2023

Dr. Mike Hegedus
School of Engineering Science
Simon Fraser University
British Columbia, V5A 1S6

ADAScooter

RE: ENSC 405W Requirements Specification for Company 2

Dear Dr. Mike Hegedus,

The attached requirements specification document has been created to specify the key requirements of our proposed product stages, being the proof-of-concept, engineering prototype, and production version. Our company is committed to introducing a modern safety solution to electric-scooter riders and nearby road users through the use of a modular advanced driver assistance system (ADAS).

To do this we will use a sensor(s) to map out the immediate area surrounding the rider and analyze the data in real-time with kinematics principles to determine if there is a possibility of an incoming collision. With such data we can then apply multiple solutions from making sound for simple proximity awareness to full on automatic braking in the case of a certain collision. The module would also include a display for informative purposes, user input and possible system calibration.

In this document, we will go over the justification of the chosen requirements as well as thorough analysis of our customers' needs.

ADAScooter can be contacted about any questions and concerns regarding this document through our CCO, Alejandro Lorenzo-Luaces, who can be reached at alorenzo@sfu.ca.

Enclosure: Requirement Specifications Document

Sincerely,

Alejandro Lorenzo-Luaces, CCO

Lorenzo-Luaces
Signature of CCO

Feb 12, 2023
Date

SIMON FRASER UNIVERSITY
ENGAGING THE WORLD

Requirements Specification

Modular E-Scooter Advanced Driving Assistance System (ADAS)

ADAScooter

CEO	Robert Respicio (rrespici@sfu.ca)
CFO	Makan Mousavifard (makanm@sfu.ca)
CCO	Alejandro Lorenzo-Luaces (alorenzo@sfu.ca)
CLO	Pouria Khodabakhsh (pkhodaba@sfu.ca)
CTO	Chris Tesar (ctesar@sfu.ca)
COO	Gregory Sheppard (gjsheppa@sfu.ca)

Feb. 12, 2023

Abstract

Electric scooters are becoming more popular than ever as they present a cheaper, cleaner and more accessible form of transportation when compared to motor vehicles and even public transportation. However, they are statistically proven to be many times more likely to be involved in an accident when compared to their 2-wheeled counterpart, the bicycle. ADAScooter would like to introduce solutions to this problem by means of a modular ADAS for e-scooters. This document explains the requirements for each of the proposed product stages being: Proof-of-Concept, Engineering Prototype, and Production Version. It also goes over the main system overview as well as specific electrical, mechanical, software, safety, and functional requirements.

List of Figures

List of Tables

Glossary

The following table is a list of terms mentioned throughout this requirement specification document.

Term	**Definition**
ADAS	Advanced Driver Assistance System

Table of Contents

1 Introduction

The use of electric scooters in the populated city environments pose certain safety risks on the driver as well as pedestrians and other vehicles. ADAScooter's mission is to reduce these risks with a focused approach on enhancing the safety of the e-scooter for the driver and pedestrians, and to prevent accidents with other vehicles. The Advanced Driver Assistance System (ADAS) is ADAScooter's solution which can notify the driver of the possible sources of collisions in the surroundings and activate a braking mechanism to prevent collisions. In addition, the system signals the presence of the e-scooter to other road users and pedestrians which results in higher spatial awareness to reduce accident risks.

Our system utilizes detection and ranging sensors, which generates a point cloud mesh which can be used to map out the surroundings of the user. This can be interfaced with a braking system to automatically slow or halt the scooter if the system determines a collision will happen.

The motorway can be unpredictable and dangerous. Under B.C law, e-scooters are required to operate along bike lanes and city roads [1], and low-powered vehicles like e-scooters are bearing greater risk of injury compared to motor vehicles [2]. By integrating our ADAS system which avoids and prevents collision paths, e-scooter riders, cars and pedestrians will be safer on the road.

1.1 Background

E-Scooters are an increasingly popular form of transportation around the world. Cities in B.C such as Coquitlam, Nanaimo and Vancouver along with 9 other cities and townships have pilot programs that allow e-scooter riders to operate on bicycle lanes and along the streets. Cities such as North Vancouver, Richmond and Kelowna also allow companies such as Lime to rent e-scooters to the public. However, operating e-scooters come with some risks. Because e-scooters are often operated on motor-ways, 80% of e-scooter crashes involve cars [3]. As can be seen in Figure 1.1.1, e-scooters typically share the road with pedestrians, cyclists, cars and other e-scooter riders. Other risk factors include alcohol impairment, riding between 10pm-6am and being between the ages 18-29 years [4]. To address these risk factors, we propose a detection and ranging sensor that detects objects and applies brakes if a collision is imminent. Our solution addresses many of these risk factors such as riding at night which impairs rider vision and visibility of others. These risk factors can be mitigated by a system that automatically brakes at critical times and reduces the reliance of the rider for safety.

Figure 1.1.1: Pedestrians, scooters, cyclist along side vehicles [3]

Our market is targeting entities with an e-scooter or a fleet of e-scooters that would benefit from a retrofittable ADAS system. This includes e-scooter share companies, who can decrease their liability of passenger injury. Other markets such as e-scooter manufacturers may want to implement and market a similar ADAS technology to their product without designing the ADAS system themselves. Finally, individual e-scooter owners and parents of teens who are concerned for the riders safety.

1.2 Current Solutions and Research

The current research on the potential dangers of the e-scooters have recently started in Canada via pilot programs [6][7][8], though the technical solutions are not yet available domestically. Meanwhile, companies such as Segem have introduced e-scooters with ADAS integrated onto them, but they are currently in development and not yet available for consumers in our targeted market [9][10]. In addition, their solution is built into the manufactured product, and their e-scooter is around $4,000CAD, which makes it an expensive, undesired option for many. Figure 1.2.1 shows the proposed Segem NEV e-scooter.

Figure 1.2.1: The NEV Segem E-scooter [14]

Some shared e-scooter services are developing smart systems for their e-scooters' pavement riding and parking, but these are available only in select cities with a subscription [11][12]. Furthermore, the safety of the rider and pedestrians is not at the core of these solutions. Other solutions exist to address safety issues for the riders, such as the Garmin Varia Radar Tail Light. This solution only alerts the rider when a vehicle is approaching from behind and does not address the needs of other road users safety such as obstacles beside and in front of the e-scooter [13].

1.3 Further Possible Developments and Optimizations

Given that ADAScooter meets the key requirements described below, further possible developments and optimizations have been considered. Each of the following considerations were conceived during research, but deemed out of scope due to time limitations within the capstone period. Given more time, ADAScooter have considered: firstly, optimizing the braking control software by considering inertia calculations. By doing so, the user would experience less abrupt braking. Braking could also be further improved by switching to a machine learning based algorithm to optimize braking conditions in a multitude of scenarios. Additional features have also been considered for general improvements to awareness and safety. Installation of a rear view camera to improve vision during turns and steering correction with lane assist could provide a similar driving experience to modern cars.

1.4 Scope

The objective of this document is to specify and outline the requirements of the Modular E-Scooter Advanced Driving Assistance System (ADAS) for each of the proposed product stages. Requirements are to be organized and apply tracing using the Requirements Classification outlined in *section 1.6*, and must be quantifiable, testable, and appropriate.

Sections out-of-scope for this document include design specification and assembly construction diagrams.

1.5 Intended Audience

This document is intended to be a living reference for ADAScooter to meet customer requirements, as well as introduce the requirements within to its customers, potential business partners, to Dr. Mike Hegedus, and to the rest of the ENSC 405W teaching team.

1.6 Requirement Classification

The following convention will be used to specify requirements in this document:

Req {Encoding [A-C]}-{Section}.{Subsection}.{Requirement Number}

The requirements in this document are listed in order of priority. Requirements below other requirements are required to achieve the primary requirement in that section. For example:

Req A.1.1.1 - Primary requirement for section 1.1.
Req A.2.1.1 - Primary requirement for section 2.1.

Encoding	Stage of Development
A	Proof-of-Concept
B	Engineering Prototype
C	Production Version

Table 1.6.1*: Requirements Encoding Classification*

Requirements under the "A" encoding are designated to be met in order to confirm the full functionality of the system nodes, while requirements under the "B" encoding are designated to be met by the end of the ENSC 440 term. Lastly, the "C" encoding designates requirements to be met by the final production version of the device.

2 System Overview

This section provides a comprehensive overview of the safety modular device designed for e-scooters. The device is equipped with a detection and ranging sensor that continuously monitors the immediate surroundings for potential obstacles and alerts the driver and nearby individuals in the event of a high chance of collision. The alert comes in two forms: audio and visual. A speaker can alert the driver and the surrounding pedestrians of an approaching e-scooter, and a small display screen to accentuate nearby obstacles to the rider. In emergency situations, the device will actuate the e-scooter's built-in braking system and automatically cut off the throttle, preventing collision and any potential accidents from occuring. A microprocessor is responsible for receiving and interpreting analog signals from the sensor to make a decision on whether an obstacle has been detected, enabling the device to perform the necessary actions. The entire device is powered by a rechargeable battery, designed to provide sufficient power to run for the duration of a single charge of an e-scooter battery, ensuring uninterrupted operation and reliability. The implementation of this device is critical in ensuring the safety of e-scooter riders and those in the vicinity. Figure 2.0.1, shows the overview block diagram of the system.

This safety modular device is designed to be portable and user-friendly, with the capability to be easily mounted on any e-scooters, providing users with the convenience of installation and use.

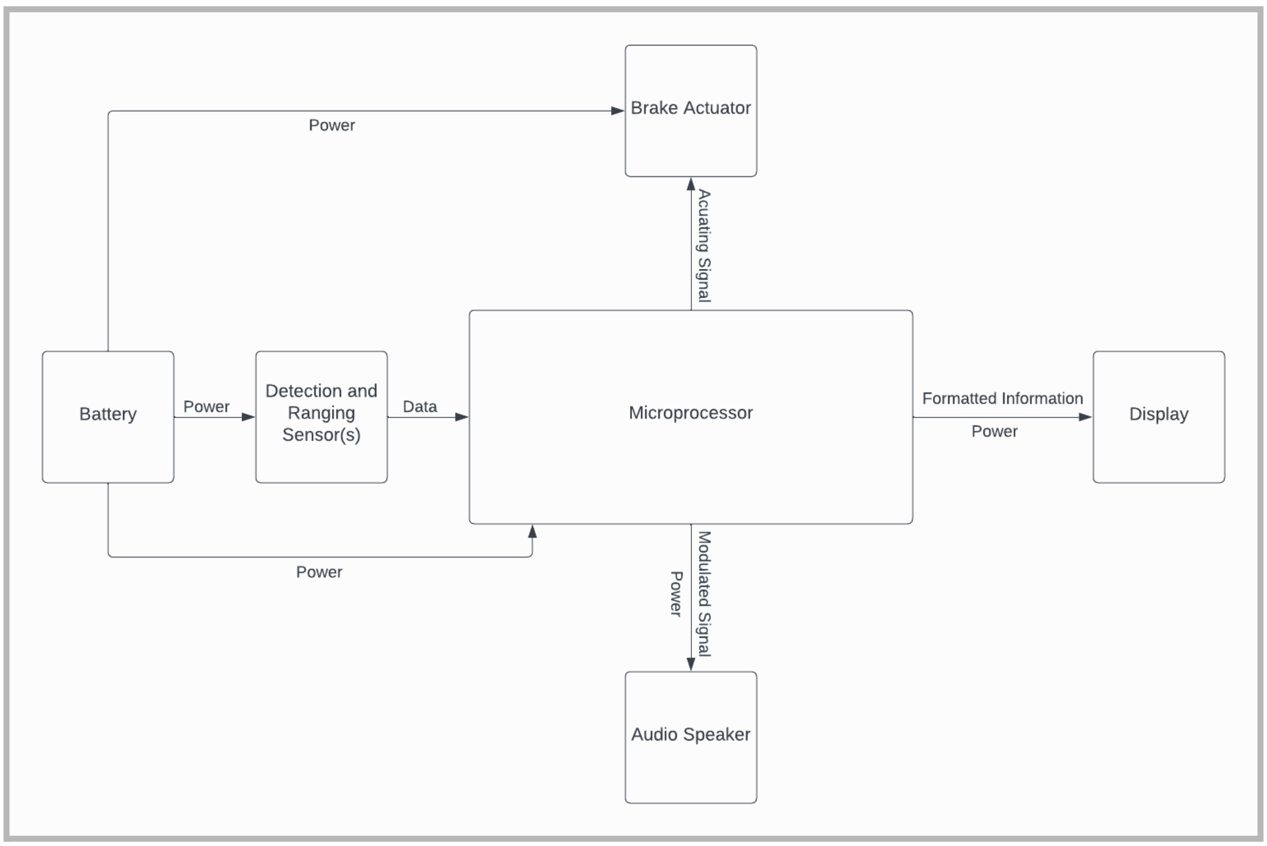

Figure 2.0.1: *The Block Diagram of the System Overview*

3 General Requirements

The following section outlines the general requirements for the ADAS modular device as a whole. It is important to note that these requirements provide a broad overview of the system's capabilities and limitations. A more detailed description of the requirements for each component of the system will be provided in subsequent sections. The purpose of this section is to ensure a clear understanding of the overall functionality of the system and to provide a foundation for the subsequent component-specific requirements.

3.1 Functional Requirements

Table 3.1.1 displays the comprehensive list of general requirements that define the functionality of the system.

Requirement ID	Requirement Description
Req A-3.1.1	The device will be able to detect objects in its proximity as well as their velocity.
Req A-3.1.2	In the event an object is detected in the path of the scooter, the device will attempt to prevent collision by safely applying the brake.
Req A-3.1.3	The speaker will generate a sound at audible amplitude for the rider and pedestrians nearby for proximity awareness scenarios.
Req A-3.1.4	The screen displays real time feedback to the user.
Req B-3.1.5	The device will have a button(s) for user input
Req C-3.1.6	The device will identify objects around it and distinguish between cars, pedestrians, and other obstacles.
Req C-3.1.7	The device will notify the user if current conditions prevent the detection system from working properly.

Table 3.1.1: *Functional Requirements*

The above requirements were chosen as they best represent the functionality we are proposing our project will have. The device needs to be able to detect objects in the proximity as well as be able to extrapolate velocity data to be able to perform collision calculations following the principles of kinematics. If a collision or near miss is predicted, the module would apply the brakes and/or make a noise with the speakers to warn both the rider and others nearby. A display is necessary for relaying valuable information to the user such as battery life as well as makes it possible for user input through the use of an interactive menu.

3.2 System Requirements

Table 3.2.1 presents a list of requirements that must be satisfied for the proper operation of the system.

Requirement ID	Requirement Description
Req A-3.2.1	The device is a module that can be mounted onto a basic e-scooter model.
Req A-3.2.2	The device will be battery powered.
Req B-3.2.3	The device will have a user interface in which the user may adjust settings and calibrate the system.
Req B-3.2.4	The device will allow the user to calibrate the braking system to work with their e-scooter model.
Req B-3.2.5	The device will be easily installable by the user on various e-scooter models.
Req B-3.2.6	The device will be easily removable by the user without causing damage to the module or the e-scooter.
Req B-3.2.7	The device will be able to adjust its detection proximity threshold depending on its speed.
Req B-3.2.8	The device’s interface will not impede on the user’s ability to drive in conditions proper for operation.

Table 3.2.1: *System Requirements*

The ADAScooter’s product is a modular solution that is to be installed onto an e-scooter model as the proof-of-concept. The system also operates as an independently powered device which therefore needs to be battery powered. As its prototype, the module should be retrofittable onto various e-scooter models; therefore, it should be easy to set up and calibrate, and to be removed without damaging the system components or the e-scooter itself. In addition, the prototype would allow the user to have more options to customize the settings as needed, for the purposes such as setting an obstacle detection radius based on the speed, as well as the braking actuator calibration. Lastly, it is important that the display does not interfere with the driver's attention to the road, and the overall system must not impede their ability to drive in proper operation conditions.

4 Hardware Requirements

The system consists of the hardware requirements in mechanical and electrical domains, for the functionality of the components and in accordance with the overall purposes of the device. These are related to the speed control through the brake actuation and throttle cut off, as well as the requirements the components must meet in order to operate practically and safely.

4.1 Mechanical Requirements

Table 4.1.1 enumerates the mechanical specifications and requirements for the safety modular device, providing a clear and detailed understanding of its physical characteristics.

Requirement ID	Requirement Description
Req A-4.1.1	The device's brake actuator will provide enough force to actuate the e-scooters brake lever.
Req A-4.1.2	The device's brake actuator will actuate quickly enough to brake within the stimulus period.
Req A-4.1.3	The actuated force will bring the e-scooter to a full stop if needed, within at least 9m from the point at which the brakes are applied.
Req A-4.1.4	The device will be able to decelerate the e-scooter in a safe manner.

Table 4.1.1: *Mechanical Requirements*

The e-scooter's braking will be also controlled by the system prototype, through output signals from the microprocessor onto an actuator applying force onto the native brake lever. The resulting actuated force must be applied in time and at proper force, in order to safely slow the e-scooter, and to a full stop within 9m from the time of actuation as outlined by the BC pilot program regulation [1]. Furthermore, too rapid of a deceleration can result in the driver falling off of the e-scooter, so this must also be done in a safe manner.

4.2 Electrical Requirements

Table 4.2.1 outlines the electrical requirements for the device, including specification for the sensor, microprocessor, power supply, and other critical components providing a comprehensive understanding of the electrical aspects of the system.

Requirement ID	Requirement Description
Req A-4.2.1	Hardware components will be powered within safe operating limits.
Req A-4.2.2	The microprocessor must process input data fast enough to not create debilitating latency.
Req A-4.2.3	Sensitive hardware components will have a voltage regulator.
Req A-4.2.4	System battery should last the same time as an average e-scooter battery life.

Table 4.2.1: *Electrical Requirements*

The safe operation of the hardware components is an important requirement of the system, which is listed in the table above for both the safe power limits and the use of voltage regulators for sensitive parts. It is also crucial for the system to process the data in real-time and fast enough for the safe functionality of the device; therefore, the latency of the microprocessor must be very small. Lastly, as the module is powered by its own battery source, it must keep up with that of the e-scooter to ensure reliability and user's safety.

5 Application Requirements

The ADAScooter's solution will meet the following application requirements to ensure system functionality and effective user experience. This involves the communication between system nodes, inputs and outputs, as well as the user interface. Table 5.1.1 lists these requirements below.

5.1 Software Requirements

Requirement ID	**Requirement Description**
Req A-5.1.1	The software will read sensor data to respond and process stimulus within the time required to brake.
Req A-5.1.2	The software needs to be able to reliably detect objects moving at 24km/h relative to the rider and react to high risk of collision.
Req A-5.1.3	The software will provide seamless direct communication between the input and output components.
Req A-5.1.4	The software will not crash during operation under any circumstances.
Req A-5.1.5	The display will provide intuitive and concise visual feedback to inform the user of the current states of the system and surroundings.
Req A-5.1.6	The software will restrict the user from adjusting settings or calibration while the device is in motion.

Table 5.1.1: *Software Requirements*

The software plays a central role for the system, as it provides the communication between the system components. It is critical that the software works accurately, reliably, and does not crash during operation, to be able to read and process the sensor data, and determine the conditions in which controlled braking is to be applied. The response time must well cover the maximum (relative) speed of 24 km/h as outlined by the BC pilot program regulation. In addition, the data from the system are to be formatted for the purpose of visual feedback to the user through the display. To avoid distracted driving, the software should also restrict the user from making adjustments and calibrations during operation.

6 Safety and Sustainability Requirements

This section outlines the overarching goals of ADAScooter with regards to safety and sustainability. The primary objective of this project is to increase the safety of riders and those in the vicinity of the e-scooters, and to ensure that the product does not compromise any existing safety measures. Following the hierarchy of hazardous controls, as shown in Figure 6.1.1, our solution falls under *engineering control* as we are trying to isolate people from the hazard. Pure elimination or substitution is not a possibility. Additionally, sustainability is a key consideration in the design and development of this device, as it is important to minimize any negative impact on the environment. The requirements outlined in the subsequent sections are intended to ensure that ADAScooter is both effective and sustainable, contributing to a safer and greener future.

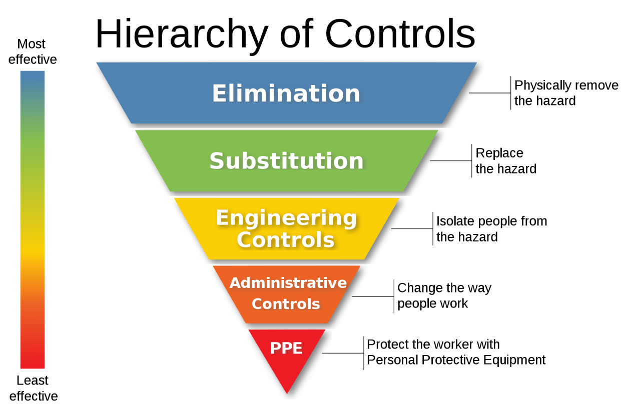

Figure 6.1.1: Hierarchy of Controls

6.1 Operational Safety Requirements

Table 6.1.1 lists the operational safety requirements for ADAScooter, ensuring that its use is safe and reliable in real-world scenarios.

Requirement ID	**Requirement Description**
Req B-6.1.1	The device will meet a weather-proof rating of IP44.
Req B-6.1.2	The device will not have any sharp edges that can cut the end user under normal operating circumstances.
Req B-6.1.3	The device will fully enclose all electronics and circuitry such that it shall not pose an electrical hazard under normal operating conditions.
Req C-6.1.4	The packaging conforms to ISO 28219:2017 standards for product labeling and marking requirements.

Table 6.1.1: *Operational Safety Requirements*

6.2 Sustainability Requirements

Table 6.2.1 outlines the sustainability requirements for the device, providing guidelines for environmentally responsible design and operation, and ensuring its long-term impact is positive and sustainable.

Requirement ID	Requirement Description
Req B-6.2.1	Engineering prototypes of the device will be disassembled and parts donated or used in other projects at the end of the capstone period.
Req C-6.2.2	The device’s firmware will be externally flashable by the end user to provide critical updates.
Req C-6.2.3	The device’s main components will be reasonably replaceable or repairable by the end user.
Req C-6.2.4	The device packaging will consist of biodegradable or recyclable products.
Req C-6.2.5	The device's user and instruction manual will be provided electronically.

Table 6.2.1: *Sustainability Requirements*

7 Conclusion

The vision of this project is to make e-scooters safer to ride for the user, as well as others on the road. By utilizing detection and ranging of sensors and braking system, e-scooter users will be less prone to accidents and injury for themselves and those around them. The system will detect objects in close proximity, determine when an obstacle may collide with the user and respond in real-time, providing the proper actuation force to the brakes required to prevent a collision with minimal latency. The product will have an easy set up and calibration, be easy to use and be weather-proof for use in moderate to extreme conditions.

Our company strives for product excellence and strict adherence to engineering principles and processes. Our design philosophy for the ADAS system is reliability, efficiency, safety, and accessibility. We strive to create a system that can be consistently relied upon for safety and be easily accessed by all e-scooter users. The team at ADAScooter is dedicated to delivering an exceptional product that fulfills all stakeholder requirements and constraints.

8 Appendix

8.1 Requirements Test Plan

ADAScooter - Modular E-Scooter Advanced Driving Assistance System (ADAS) Test Sheet		
ADAScooter - Company 2		Date:
Mechanical Tests		
The brake actuator is able to actuate the brake fully:	☐ **PASS** ☐ **FAIL**	Comments:
The device is mountable without modification to the e-scooter:	☐ **PASS** ☐ **FAIL**	Comments:
The brake actuator actuates when visual stimulus is detected:	☐ **PASS** ☐ **FAIL**	Comments:
The device meets a rating of IP44:	☐ **PASS** ☐ **FAIL**	Comments:
Computer Vision Tests		
Detects objects 15 m away:	☐ **PASS** ☐ **FAIL**	Comments:
Detects objects moving 24km/hr relative to the device:	☐ **PASS** ☐ **FAIL**	Comments:
Differentiates between objects that it will crash into and objects it won't:	☐ **PASS** ☐ **FAIL**	Comments:
Electrical Tests		
The speaker is able to generate a sound 80 dB within a radius of 2 m:	☐ **PASS** ☐ **FAIL**	Comments:
The module's battery lasts the same amount of time as the e-scooters battery:	☐ **PASS** ☐ **FAIL**	Comments:
The battery outputs 12 V @ 2 A:	☐ **PASS** ☐ **FAIL**	Comments:
Software Tests		
The software is stable for t >> battery life:	☐ **PASS** ☐ **FAIL**	Comments:
Software restricts changing settings while the e-scooter is in motion:	☐ **PASS** ☐ **FAIL**	Comments:

8.2 Proof of Concept Appendix

By April 12th 2023, ADAScooter will have a “Proof of Concept” product ready for demonstration. The following features and requirements will be delivered:

- The system will be able to predict future collisions within areas covered by the sensor
- The system will stop the e-scooter when an object is within a collision path
- The system will use a display to relay information to the user
- The system will be mounted onto a e-scooter

The following is a list of key problems that need to be addressed for ADAScooter to succeed in the Proof-of-Concept demo.

- The device must be mounted safely and securely
- Being able to apply the brakes without making the user lose control of the scooter
- Overall system latency so that collisions can be predicted and action can be taken before said collision occurs
- The ranging sensors must cover all blind spots
- Differentiate the obstacles which are on the collision path from those which are not

9 References

[1] “Electric kick scooter pilot project regulation - 90 2021 - gov.” [Online]. Available: https://www.bclaws.gov.bc.ca/civix/document/id/crbc/crbc/90_2021. [Accessed: 12-Feb-2023].

[2] V. Chander, “E-bikes show distinct pattern of severe injuries,” *Reuters*, 25-Dec-2019. [Online]. Available: https://www.reuters.com/article/us-health-ebike-injuries-idUSKBN1YT0MV. [Accessed: 12-Feb-2023].

[3] T. Bradshaw, “Electric scooter boom faces US city limits,” *Subscribe to read | Financial Times*, 26-Apr-2018. [Online]. Available: https://www.ft.com/content/48d635b0-46de-11e8-8ee8-cae73aab7ccb. [Accessed: 12-Feb-2023].

[4] C. R. Cherry, “80% of fatal e-scooter crashes involve cars – new study reveals where and why most collisions occur,” *The Conversation*, 13-Sep-2022. [Online]. Available: https://theconversation.com/80-of-fatal-e-scooter-crashes-involve-cars-new-study-reveals-where-and-why-most-collisions-occur-158609. [Accessed: 12-Feb-2023].

[5] H. Stigson, I. Malakuti, and M. Klingegård, “Electric scooters accidents: Analyses of two Swedish accident data sets,” *Accident Analysis & Prevention*, vol. 163, p. 106466, 2021.

[6] https://vancouver.ca/streets-transportation/electric-kick-scooters. [Accessed: 25-Jan-2023].

[7] https://www.ontario.ca/page/electric-kick-style-scooters-e-scooters. [Accessed: 25-Jan-2023].

[8] “E-scooters in Ontario: What are the dangers?,” Horowitz Injury Law, 05-Sep-2021. [Online]. Available:https://www.horowitzinjurylaw.com/2021/09/05/e-scooters-in-ontario-what-are-the-dangers/. [Accessed: 25-Jan-2023].

[9] https://www.autoevolution.com/news/segem-launches-the-futuristic-nev-touts-it-as-the-world-s-first-adas-powered-scooter-201186.html. [Accessed: 26-Jan-2023].

[10] The world's first vehicle of its kind with radar powered Adas,” NEV - World's most advanced vehicle of its kind - Segem Micromobility. [Online]. Available: https://www.segem.city/. [Accessed: 26-Jan-2023].

[11] https://www.traffictechnologytoday.com/news/multimodal-systems/ai-enabled-computer-vision-for-e-scooters-unveiled-by-lime.html. [Accessed: 26-Jan-2023].

[12] “Pathpilot,” *Drover*, 23-Sep-2022. [Online]. Available: https://drover.ai/path-pilot/. [Accessed: 12-Feb-2023].

[13] G. L. or its subsidiaries, “Garmin Varia™ RTL515: Bike Radar and Tail Light,” Garmin. [Online]. Available: https://www.garmin.com/en-CA/p/698001. [Accessed: 26-Jan-2023].

[14] Segem, “Segem E-Scooter,” *NEV - World most advanced vehicle of its kind - Segem Micromobility*. [Online]. Available: https://www.segem.city/explore-nev/. [Accessed: 12-Feb-2023].