Managing the Risks of Lithium-ion Micro-Mobility Devices Within the Shelter System

Project Requirements

Prepared By: Daniel Dot, Ethan Xiao, Mazin Mukhtar, Oliver Cai, and Taha Syed
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Executive Summary

The Toronto Shelter System (TSS) provides temporary housing and accommodation for citizens as well as health and mental well-being services. Due to multiple lithium-ion fires caused within these shelters, our client, Ryan Duggan, Director of Safety and Compliance at the City of Toronto, requests a design to manage the risks associated with these fires. The modification of lithium-ion batteries within micro-mobility devices have increased the risks of fires. However, banning ownership of these devices within the shelter system cannot be considered as residents rely on them for day-to-day life.

The issue identified is the lack of a safe and secure storage system for lithium-ion batteries belonging to micro-mobility devices. There is a need for a safe and secure way to store these lithium-ion batteries for the TSS. There are currently 49 active shelters in Toronto, though due to a client request the project will be initially designed with the 545 Lake Shore Blvd W shelter in mind. The City of Toronto occupies these shelters on short-term leases with little to no extra interior capacity; thus the design will operate outdoors in Toronto.

Consequently, the design will be subject to temperatures ranging from -26.3°C to 37.9°C, peak rainfall of 12.8 cm a day, and peak snowfall of 39.9 cm a day. The City of Toronto can provide up to 200A of electric current through 120/240V connections for any required electrical work. Living factors include wildlife such as squirrels, coyotes, foxes, and raccoons, all posing risks to a potential design. Additionally, the people of Toronto may attempt vandalism and theft of the device or design.

The TSS and Related Services are the main stakeholders of the design. Additional stakeholders include the Toronto Fire Services' Fire Prevention Division, responsible for inspecting the design for fire safety. The Toronto Facilities Management Division is responsible for construction and maintenance and Toronto Transportation Services ensures the design does not interfere with city transportation. Relevant users and operators include staff and residents of the TSS.

The primary function of the design is to store lithium-ion batteries belonging to micro-mobility devices. To enable this, secondary functions are to store the device, charge the device, secure the device, and regulate battery temperature. Objectives include security, durability, safety, portability, and space efficiency. The design should have an ANSI A156 Security Grade 1 lock to resist theft and should have a compressive strength of at least 750 MPa to endure unexpected loads. The design should be capable of withstanding at least 1000℃ temperatures to contain lithium-ion fires. The design should weigh less than 91 kg to be easily transportable and should take up less than 0.825 m^2 of space per device stored to be space efficient. The design must be able to withstand environmental factors (wind, temperature, rain/snowfall), must comply with Ontario Fire Code and Building standards, and must be resistant to low-profile theft attacks.

1.0 Introduction
The Toronto Shelter System (TSS) provides temporary housing and related services for those without personal accommodations [1]. The client, Ryan Duggan, Director of Safety and Compliance at the City of Toronto, seeks to mitigate the risk of fires caused by lithium-ion batteries in micro-mobility devices in these shelters. This document outlines the problem, service environment, stakeholders, and requirements for a successful solution. The design will be based on the shelter located at 545 Lake Shore Blvd W Toronto, ON M5V 1A3 [2].

Figure 1. Exterior of Shelter (facing SE) (Image from Google Earth [2])

2.0 Problem Statement
The TSS has experienced over 10 lithium-ion fires in recent years due to modified micro-mobility devices (Appendix A). Lithium-ion battery-related fires may result from physical stress, improper battery installation, or high-temperature environments [3]. The modification of lithium-ion batteries can cause improper insulation of components, short circuits, overcharge, and over-discharge. A ban on ownership of these devices cannot be considered due to their value to the residents (Appendix A). Therefore, a means of safely storing these batteries must be developed. The design will be used by residents and operated by staff of the TSS.

2.1 Gap
The gap is the lack of a safe and secure storage system for lithium-ion batteries belonging to micro-mobility devices for residents in the TSS.

2.2 Need
There is a need for a design to safely and securely store lithium-ion batteries belonging to micro-mobility devices for residents within the TSS.

2.3 Scope

The scope of this project involves all TSS locations. The client has stated that the City of Toronto is planning on prohibiting lithium-ion micro-mobility devices from entering these shelters. Designing an indoor solution is out of scope (Appendix A). As several shelters operated by the City of Toronto are short-term leases, altering the shelters is out of scope. Due to this, solutions must be designed to operate externally and are subject to relocation. The client has indicated a specific shelter, located at 545 Lake Shore Blvd West, that will be used to test our design and determine its effectiveness. Our design must accommodate all shelters, but we use this shelter to gather data. Below, in Figure 2, a detailed drawing highlights the parameters of the location.

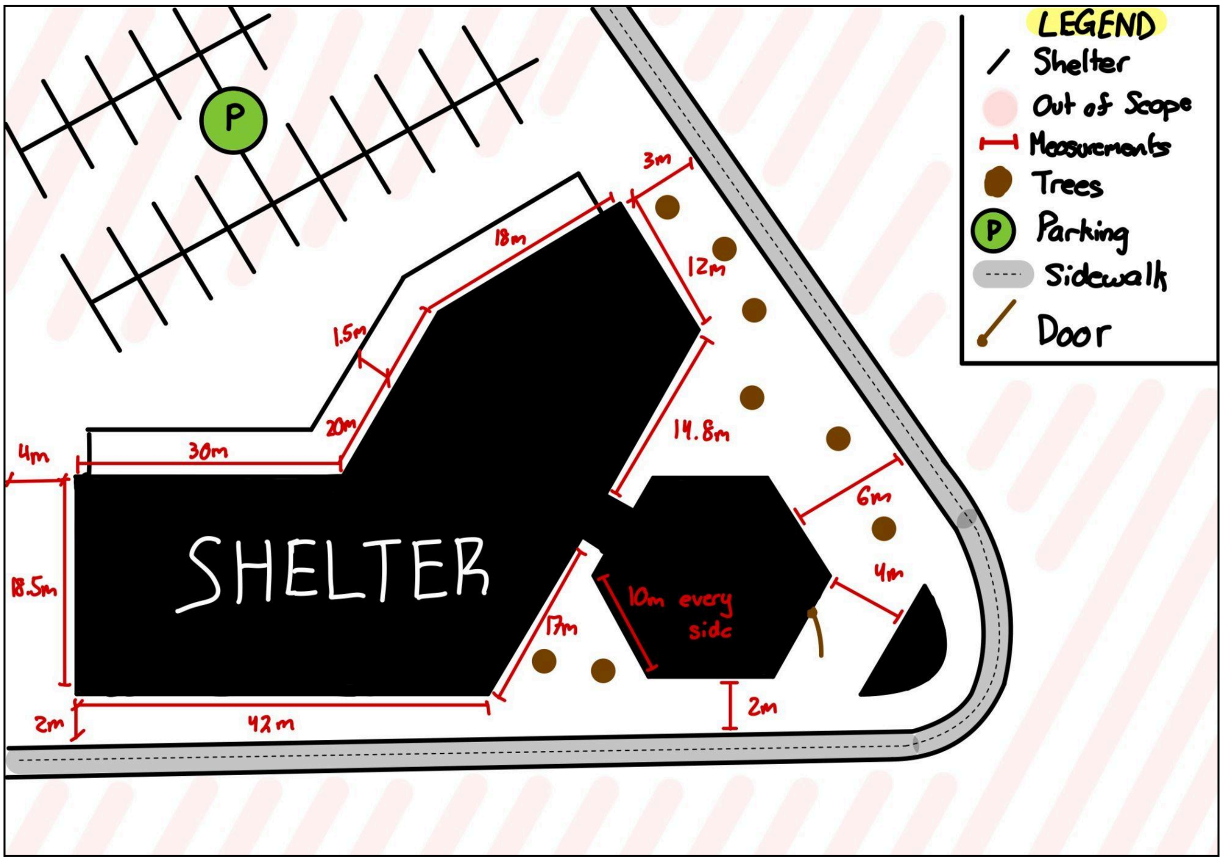

Figure 2. Scope and Dimensions of the design (From Site Visit on Friday, February 14, 2025).

3.0 Service Environment

This section outlines the service environment, focusing on the physical, virtual and living aspects present around the TSS buildings.

3.1 Physical environment

This section details the physical factors surrounding shelters in Toronto that must be considered.

3.1.1 Location

Our client is interested in implementing our design throughout the TSS. Figure 3 depicts the various locations of the TSS shelters.

Figure 3. Locations of shelters in the City of Toronto [2].

3.1.2 Temperature

The City of Toronto has various periods of extreme weather throughout the year, which must be taken into consideration for our design. As seen in Figure 4 Toronto averages a high of 23℃ throughout the summer months. In the winter months, Toronto averages a low of -5℃. Since January 1st, 2000, Toronto has achieved a maximum temperature of 37.9°C and a minimum temperature of -26.3°C [4].

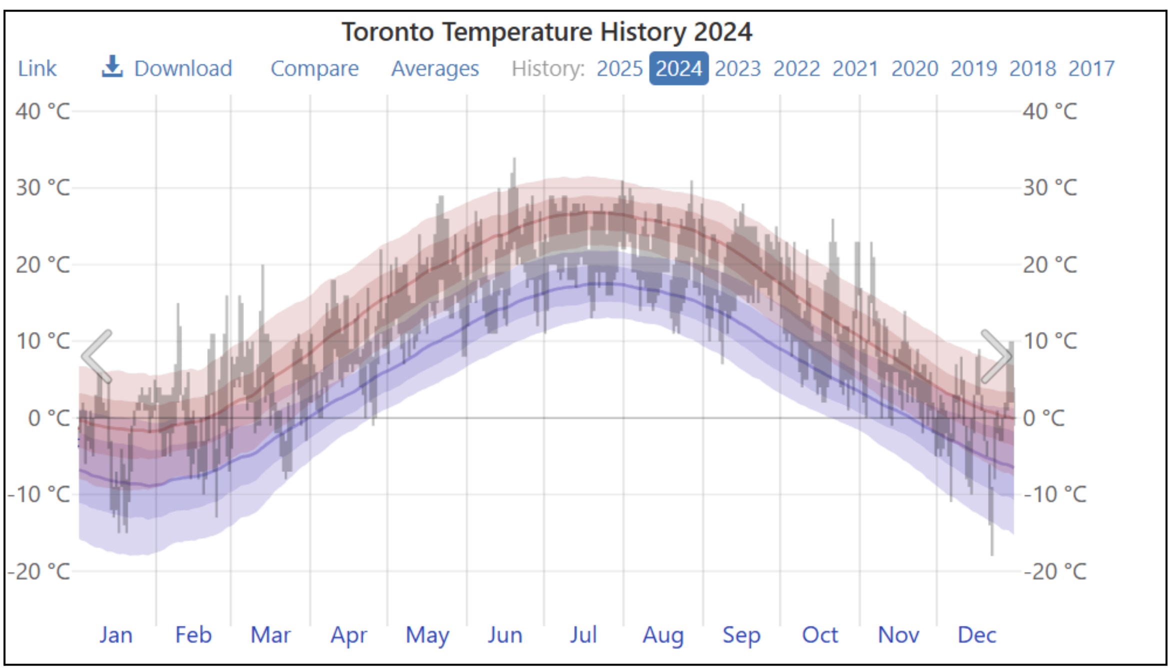

Figure 4. Graph of the temperature history in the City of Toronto throughout 2024 [5].

3.1.3 Precipitation
Precipitation, such as rain and snow, are common within the City of Toronto. In 2024, Toronto received 107.7 cm of rain and 76.4 cm of snow [6]. In that year there was a maximum daily rainfall of 12.8 cm and a maximum daily snowfall of 39.9 cm [6].

3.2 Living things
The area surrounding Toronto shelters is regularly visited by various living things that must be accounted for.

3.2.1 Wildlife
There are various species of animals present in Toronto, such as squirrels, coyotes, foxes, and raccoons, which may pose risks to an outdoor solution [7]. Squirrels have been known to chew on wires and cause property damage [8].

3.2.2 People
With multiple shelters being located in dense neighbourhoods (Figure 3), outdoor solutions will have regular interactions with the people of Toronto. There are concerns about people attempting to vandalize or use the design in unintended ways (Appendix A). In 2024, there were 120 e-bikes stolen in Toronto [9].

3.3 Virtual Environment
The client permits withdrawing power from shelters in order to charge the lithium-ion batteries. The City of Toronto delivers power at 120/240V with up to 200A of current [10]. The City of Toronto also provides free public WiFi at all shelters [11].

4.0 Stakeholders
The influence and impact of stakeholders on the project are highlighted in Table 1. They were decided by the influence vs. impact chart (Appendix A, Figure A1) and ranked in descending order of influence using pairwise comparison (Appendix A, Figure A2). Additional stakeholders are found in Appendix A, Table 4.

Table 1. Stakeholders, Influence, Impact on the Shelter System Design

Stakeholder	Description	Influence	Impact
Toronto Fire Services, Fire Prevention Division	Inspects and enforces fire safety [12] [13].	Ensures the design aligns with Ontario Fire Code [13].	Inspects the design for fire or life hazards [13].
Toronto Shelter & Support Services	Manages the TSS [14].	Ensures the design aligns with current shelter rules [15].	Oversees shelter operations and policies [16].
Toronto Facilities Management Division	Responsible for maintenance, design and construction services [18].	Ensures feasibility of the design implementation. [17].	Installs and maintains the design [17].

Toronto Transportation Services	Responsible for transportation infrastructure [19].	Ensures the design does not interfere with city transportation [20].	Evaluates effect on traffic flow and pedestrian safety [21].

5.0 Detailed Requirements

The detailed requirements define the functions, objectives, and constraints for the TSS design.

5.1 Functions

The primary and secondary functions are listed below. They are developed using functional decomposition (Appendix B) and a Black Box diagram (Appendix C).

Primary Function

- Store lithium-ion batteries belonging to micro-mobility devices.

Secondary Function

- Store device
- Charge lithium-ion battery belonging to device
- Secure and release device for user
- Regulate battery temperature

5.2 Objectives

Below in Table 2 are the objectives for the project. Detailed justifications are found in Appendix D, Table D1. A pairwise comparison was used to rank the importance of the objectives (Appendix D, Table D2).

Table 2. Objectives

Objectives		**Metric**	**Goal**	**Justification**
Security	Maximize theft-resistance	ANSI A156 Security Grade	Grade 1 [22]	Micro-mobility devices are valuable to users and at risk of theft (Section 3.2.2).
Durability	Maximize resistance to deformation	Compressive strength MPa	>750 MPa	Higher compressive strengths allow higher compressive loads to be endured without deformation [23]. Mild steel has a compressive strength of 750MPa [24].
Safety	Maximize withstandable temperature	Ignition temperature ℃	>1000℃	Materials ignite at their ignition temperature. The design should withstand lithium-ion fires, which can burn at up to 1000℃ [25].

Portability	Minimize weight	kg	<91 kg	Lightweight designs are easier to transport. The American Bicycle Bike-Shell Model 301 bike locker weighs 91 kg [26].
Space	Minimize space per device	m^2	<0.825 m^2	The design should be space-efficient to maximize the number of users while minimizing interference with city transportation. The EcoPark Standard Model bike locker occupies 0.825 m^2 per bike [27].

5.3 Constraints

Below in Table 3 are the constraints of the project, set by the client, regulations, and location of the design.

Table 3. Constraints

Constraint		**Metric**	**Goal**	**Justification**
Security	Theft Resistance	ANSI A156 Security Grade	Grade 2 [22]	Client is looking for a design that is secure from theft (Appendix A).
Durability	Wind-resistance	km/h	Must operate at up to 70 km/h.	Toronto's maximum wind speed in the last five years [28].
	Precipitation-resistance	cm	Must operate at up to 30 cm of snow.	Toronto's maximum average monthly snow and rainfall since 2000 [29].
		mm	Must operate at up to 100 mm of rain.	
Codes and Regulation Compliance	Ontario Fire Compliance	m	Must stay clear at least 1.2 m from all fire connections.	Required by Ontario's fire code [30].
		°C	Combustible materials and liquids (flash point above 37.8°C and below 93.3°C) must not be accumulated near buildings in quantities that create a fire hazard.	

	Land use	m	Must leave at least 1.5 m of sidewalk clearance.	Mandated by the Accessibility for Ontarians with Disabilities Act [31].
Storage	Temperature	℃	Must operate at temperatures below 150℃.	Maximum temperature lithium-ion batteries can reach before failure [3].
			Must operate at temperatures above -20℃.	Lowest temperature lithium-ion batteries can reach before failure [32].

6.0 Idea Generation

7.0 Idea Selection

7.1 Alternative Designs

8.0 Proposed Alternative Design

9.0 Mea
.0 Conclusion

The content outlined in the document creates a refined design space for a successful project. The primary function of this project is to store lithium-ion batteries. To achieve this safely and securely, the objectives are theft resistance, high strength, low flammability, being lightweight, and space efficiency. The major constraints are theft resistance, weather resistance, complying with fire code and land use, and temperature resistance. The next steps for the project are to begin idea generation, idea selection and determining measures of success.

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8.0 Appendix

Appendix A: Additional Stakeholders

To determine the stakeholders a stakeholder analysis chart (see Figure A1) and pairwise comparison was used (see Figure A2).

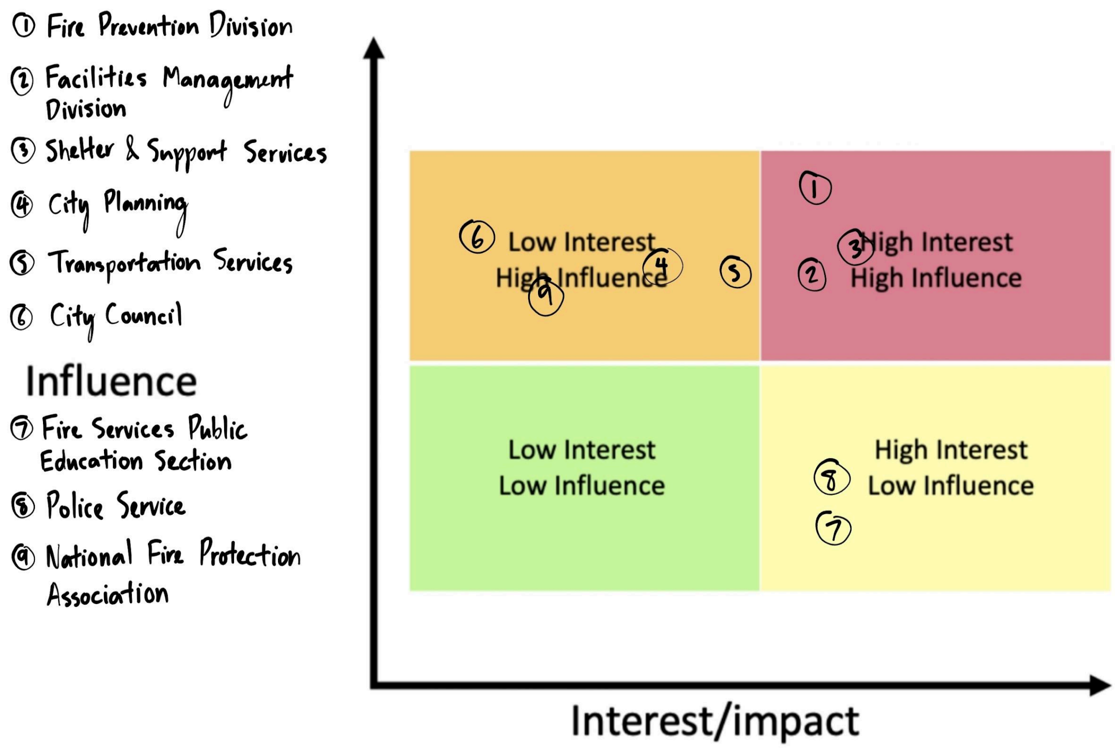

Figure A1. Stakeholder analysis chart. Drawn using Flexcil.

	Fire Prevention Division	Facilities Management Division	Shelter & Support Services	Transportation Services	Score
Fire Prevention Division	X	1	1	1	3
Facilities Management Division	0	X	0	1	1
Shelter & Support Services	0	1	X	1	2
Transportation Services	0	0	0	X	0

Figure A2. Pairwise comparison of stakeholders. Drawn using Flexcil.

Table A1. Additional stakeholders

Stakeholder	**Description**	**Influence**	**Impact**
City Planning	Division responsible for city growth and development through policy development [33].	Allocates outdoor space for the design and ensures alignment with design and development guidelines [34][21].	Might have to change existing policies or create new ones.
Toronto City Council	Legislative governing body for the City of Toronto [35].	Determines whether relevant policies are implemented [35].	Reviews and approves decisions relating to funding and policy [35].
Toronto Fire Services Public Education Section	Division responsible for public education for fire safety [36].	N/A	Informs Toronto residents of fire safety measures with the design and its usage.
Toronto Police Service	Municipal police service responsible for law enforcement in Toronto [37].	Ensures the design does not break the laws pertaining to public safety and security [37].	Prevents vandalism, damage, and theft of the design [37].

National Fire Protection Association	Non-profit organization that develops codes and standards relating to fire prevention and electrical safety [40].	Ensures the design aligns with the NFPA standards [38] [39].	Might have to change existing regulations or create new ones.

Appendix B: Black Box Diagram for Functions

Below in Figure B1 is a Black Box diagram for determining the primary function of the design

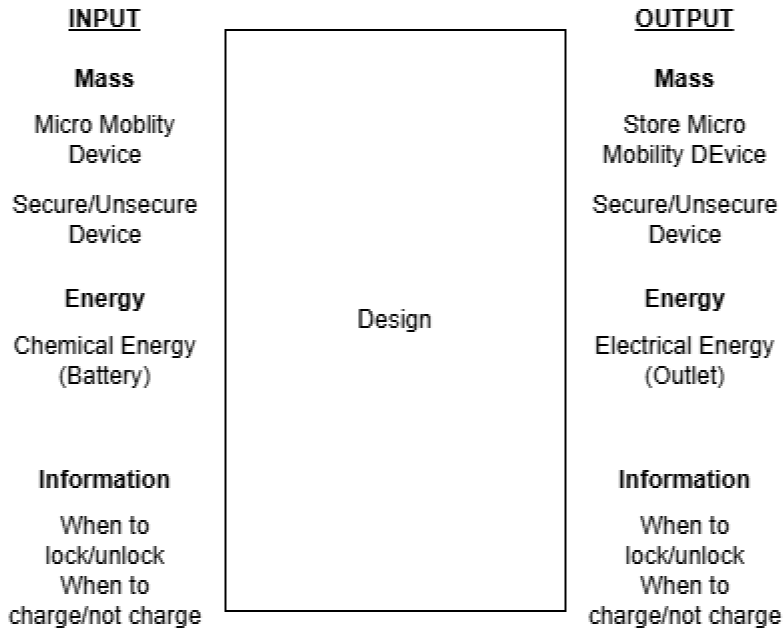

Figure B1: Black Box method for design

Appendix C: Functional Decomposition

Below in Figure C1 is a Functional Decomposition for determining the secondary functions of the design

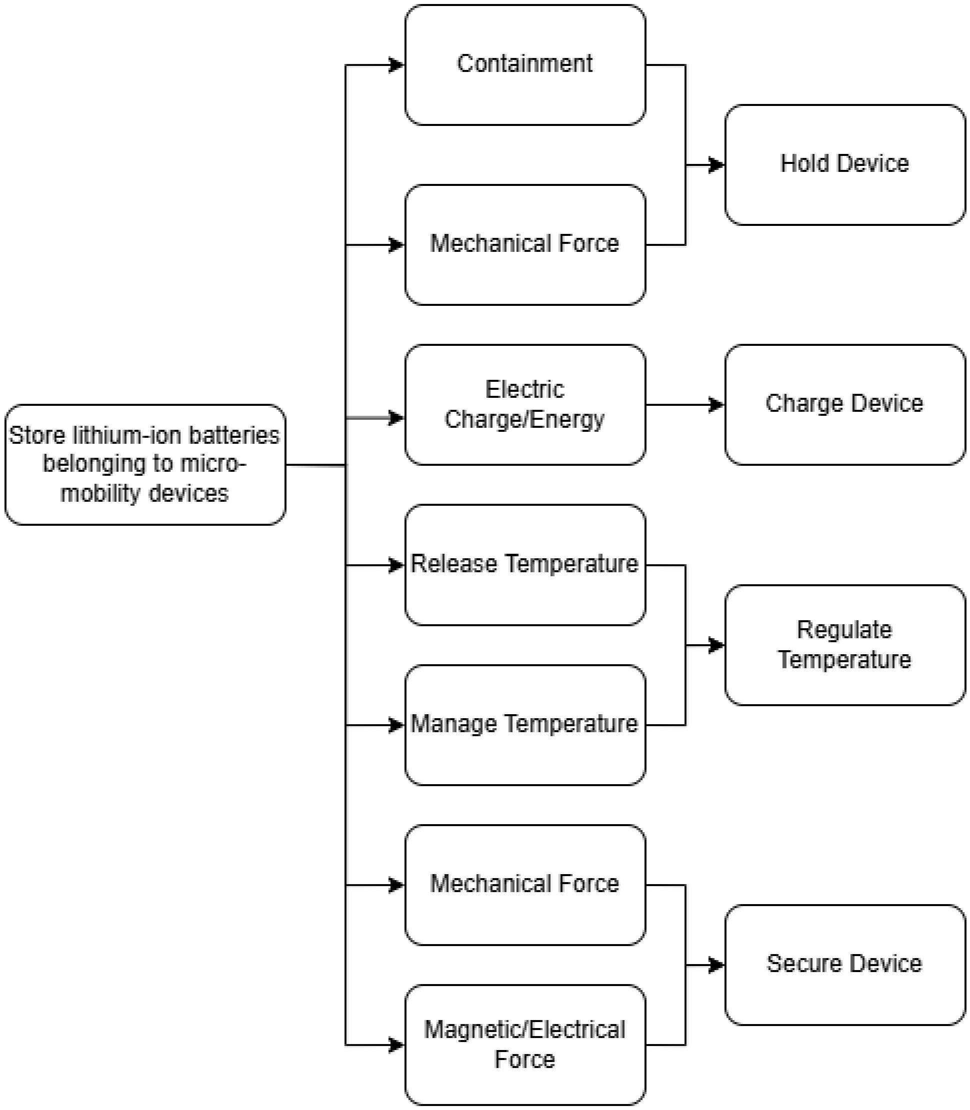

Figure C1: Functional Decomposition for the design

Appendix D: Detailed Objectives

Detailed explanation of objectives as well as the tools used by the team to determine and rank the objectives.

Table D1. Detailed justification for objectives.

Objectives		**Metric**	**Goal**	**Justification**
Security	Maximise theft-resistance	ANSI A156 Security Grade	Grade 1	Micro-mobility devices are highly valuable to users (Appendix A), and are targets of theft (see 3.2.2). To attract users, the design must offer high security. The American National Standards Institute's (ANSI) A156 series describes test requirements for various types of security hardware [22]. The security grade has three tiers that indicate resistance to attacks, with grade 1 being the highest-performing [22].
Durability	Maximize resistance to deformation	Compressive Strength MPa	>750 MPa	Materials with higher compressive strengths will be able to withstand greater compressive load without deforming [23]. Mild steel is used in building construction for framing [41]. The compressive strength of mild steel ranges from 600-900 MPa [22], of which the midpoint is 750 MPa.
Safety	Maximise temperature withstandable	℃	>1000℃	To contain lithium-ion fires, the material of the design should be resistant to catching fire. The ignition temperature is the temperature at which a material will spontaneously combust. Lithium-ion fires can burn at temperatures of 1000℃ [25].
Portability	Minimize weight	kg	<91 kg	Due to the temporary leases on certain TSS locations, the design may need to be transported (see 2.3). The lighter the design, the easier it will be to transport.

				The American Bicycle Bike-Shell Model 301 bike locker reports a weight of 200 lbs [26]. This is approximately 91 kg when converted. The EcoPark Standard Model bike locker reports a weight of approximately 410 lbs [27]. This is approximately 186 kg when converted. The Western Steel bike locker reports a weight of 250 lbs [42]. This is approximately 113 kg when converted. The Innoplast Bike-Shell Model 302 bike locker reports a weight of 280 lbs [43]. This is approximately 127 kg when converted. Of these four benchmarks, the most lightweight is the American Bicycle Bike-Shell Model 301 bike locker, weighing approximately 91 kg.
Space	Minimize space per device	m^2	$<0.825\ m^2$	The design should be space-efficient to maximize the number of users while minimizing interference with city transportation (see 4.0). The EcoPark Standard Model bike locker reports a length and width of 77.5 in and 33 in respectively for two bikes [27]. This is approximately 0.825 m^2 per bike when converted. The Cycle Sitter 2-Bike Locker reports a length and width of 76 in and 42 in respectively for two bikes [44]. This is approximately 1.03 m^2 per bike when converted. The American Bicycle Bike Storage Locker reports a length and width of 30 in and 74.5 in respectively for one bike [26]. This is approximately 1.44 m^2 when converted.

				The Innoplast Bike-Shell Model 302 bike locker reports a length and width of 74.5 in and 40 in respectively for two bikes [43]. This is approximately 0.961 m^2 per bike when converted. Of these four benchmarks, the most space-efficient is the EcoPark Standard Model bike locker, occupying approximately 0.825 m^2 per bike.

Table D2. Pairwise comparison between objectives from team discussion.

vs.	Security	Safety	Durability	Space	Portability	Score	Rank
Security		1	1	1	1	4	1
Safety	0		0	1	1	2	3
Durability	1	1		0	0	3	2
Space	0	0	0		0	0	5
Portability	0	0	0	1		1	4