helios

The Future of Urban Exploration.

2020 - Arman Amin

Increased Safety and Adoption of Last-mile Vehicles

by

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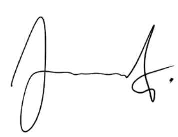
Signature : 

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Abstract

Last Mile Vehicles have been considered as a solution to overwhelming traffic congestion found in modern urban areas. While other more contemporary scenarios have been attempted to reduce the number of vehicles occupying city streets, the adoption of personalized, single-occupancy vehicles has been shown to have the largest impact. As the range of available products increases along with the capabilities (speed, distance), there are also growing concerns of safety; for the rider, other motorists, and pedestrians. Concerns regarding preventative and proactive safety measures for the rider, lack of consistency as well as the lack of a universally recognized signaling of movement intention to nearby motorists have been a crux to the widespread adoption of these single rider vehicles. By conducting user interviews and analyzing existing and future use cases, newer safety solutions were explored and further developed. The data collected helped with the design of a system of products that are built to enhance the rider's ability to safely integrate into existing urban commutes, as well as providing a synchronous, user-centered solution to the operational concerns of Last Mile Vehicles.

Acknowledgments

My deepest gratitude goes out to my brilliant parents Faramarz and Marjaneh, and wonderful sister Arezou for putting up with 5 years of ID school. None of this would be possible without them.

A special thank you also goes out to Tamara Carleton, Bill Cockayne, Ted Selker, and the Moonshot Alliance community for inspiring me to think big. This gratitude extends towards Larissa Nodwell as well for being there for me throughout this assignment, and for dealing with whatever insanity came her way.

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Shout out to Longboard Living and Boosted Inc. for being of major assistance during the research phases, ChilledCow and Geno Samuel for providing a soundtrack to all the late nights, and Dr. Yueh for being the greatest gerbil that ever existed.

Lastly, a huge congratulations to the ID graduating class of 2020. As unceremonious as this ending was, the real adventure has just begun.

Keep it real.

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1 Problem Definition

Figure 1-1 – Man and Woman standing near the railing of the river. Photo by Timur Romanov on Unsplash *https://unsplash.com/photos/osNaWvJ1D1E*

1.1 Problem Definition

Last Mile Vehicles (LMV) are personal transportation devices - empowering commuters to consider a more environmentally and space-conscious decision when traveling within a city. Since these means help alleviate traffic congestion, it is beginning to gain momentum as a viable alternative to more traditional means of transportation. As the concept begins to enter the public zeitgeist, there is a gap between these new methods of transportation, and ways of keeping the rider, as well as other commuters, safe. As the speed and capabilities of these vehicles increases, preventative and reactive safety features have not been considered. This creates a disconnect for the operator and commuters who share the road with them. This thesis proposal investigates current and experimental safety methods used during the operation of these vehicles, and document the design of a product system, including an LMV transportation device that will provide preventative security for riders, other commuters, and pedestrians within a modern urban environment.

1.2 Investigative Approach

At the time of writing this report, the micro-mobility industry is still in its infancy. While existing last-mile vehicles come in a variety of diverse form factors and riding styles, these more contemporary solutions are seen as products designed for niche groups of fragmented users. As the industry is currently in the explorative phase, the focus shall be placed on existing forms of micro-mobility; specifically, public rental solutions (bikes and electric scooters), and less standardized forms of motorized transportation. To further justify design decisions, qualitative and quantitative research methods were used. Input from advisors who specialize in the usage of last-mile vehicles, the market needs for these types of vehicles, as well as human interaction design, will also be used in this report. These areas of input will further assist in the final system design.

Research Topics

- Last Mile Vehicle properties
- User Interaction
- Safety Needs & Requirements
- Commuter & Pedestrian Safety
- Preventative & Active Safety
- Augmented Reality UX/UI
- User Ergonomics

Key Questions

- What safety needs are riders currently lacking?
- What information do riders need to telegraph to surrounding commuters
- How might we improve the comfort of riding & dismounting the vehicle?
- What contextual, at glance information would assist riders in the long run?

Method of Solution – User-Centered Design

GENERAL DESIGN METHOD FOR INDUSTRIAL DESIGN	SPECIFIC METHODS USED IN THIS THESIS
PROBLEM / OPPORTUNITY STATEMENT	**Needs Statement / Literature Review**
RESEARCH	User Research • User Profile • User Observation • Expert Interviews • Ergonomic Studies • User Activity Mapping Product Research • Literature Review • Promotional Material Review • Product Benchmarking
ANALYSIS	Analysis of Select Criteria • User Needs • Usability & Functionality • Competitive Analysis • Frequency Analysis • Aesthetics • Materials
IDEATION	Rapid Sketching Mind Mapping Final Sketches
CONCEPT DEVELOPMENT	Ergonomic Study Sketch Model Study
CONCEPT REFINEMENT	Detail Development CAD development
MODEL GENERATION	CAD Model Hard Model

TABLE 1 – INDUSTRIAL DESIGN METHOD

1.3 Background, History + Social Context

Figure 1-2 –White road bike leaning on the teal wooden wall during the daytime. Photo by Carl Nenzen Loven on Unsplash *https://unsplash.com/photos/igKjieyjcko*

Often used in supply chain management as a term for transporting goods to their destination, the "Last Mile problem" has become a portmanteau to describe the difficulties in the last leg of the journey. Public transportation acts as a major artery, moving people to and within urban environments. However, as needs and population density both increased, there was a sudden increase in traffic congestion within cities. To help alleviate the number of vehicles on the road, commuters have begun adopting "Last Mile Vehicles". Taking the form of bicycles, scooters, or skateboards (either motorized or Manual).

As the expectations of the speed of service increases, so must the speed of these vehicles. Unfortunately, so will the possibility of high impact injuries. Studies show that wearing a form of head protection will dramatically decrease your risk of death by 91%, yet there is still a substantial risk of injury for the rest of the body. It has also been documented that 71% of deaths related to LMV accidents occur in urban areas. This number is only set to increase as population numbers continue to rise. It is critical to address this problem as the global industry for LMV is expected to reach over $55,200 million by the year 2025. That isn't counting the industries that rely on these technologies to properly operate such as tourism, work, and package delivery.

As the idea of LMV becomes more prevalent, there is a need for riders to be safe while operating these machines. The importance of the individual's livelihood is an important aspect on a macro scale; the safety of an individual within a system. As more riders can navigate urban areas more safely and efficiently, the quality of life increases for everyone at a macro scale; from other commuters to pedestrians

2 Research

Figure 2-1 –Man riding a skateboard on road during the daytime. Photo by Yomex Owo on Unsplash *https://unsplash.com/photos/TuB8Za2lZ-g*

To respond to key questions about specific aspects of the project, user and product-related research was conducted. This will assist in the discovery of existing and potential users and products that will aid in the design.

2.1 User Research

To gain a better grasp of the userbase of the design solution. Primary, Secondary, and Tertiary users will need to be defined:

2.1.1 User Types

Primary User – Last Mile Vehicle Riders

Figure 2-1-1 –Group of people riding Segways. Photo by Johny Vino on Unsplash

https://unsplash.com/photos/XTpzi90i3F8

Primary users of this product system consist of those who ride them. As urban congestion increases due to rising populations, many commuters have begun choosing alternative methods of navigating these environments. This newfound increased interest in the public transit system has led to a surge in the presence of 'Last Mile Vehicles' (LMV). This new form of micro-mobility has empowered users to be able to complete the last leg of their journey in an environmentally friendly, and more conscientious way.

Secondary User – Conventional Vehicle Owners

Figure 2-1-2 –Man driving vehicle. Photo by Victor Xok on Unsplash

https://unsplash.com/photos/qd-zd2MoeE8

Secondary users consist of those who interact with the primary user while navigating through the flow of street traffic. These include more conventional vehicles such as trucks and cars. Due to the increased speed and size of these vehicles, they can prove to be a hazard to LMV riders. Similarly, riders can pose as a threat to secondary users due to their unpredictable nature.

Tertiary User - Pedestrians

Figure 2-1-3 –People crossing a street in Vienna. Photo by Jacek Dylag on Unsplash

https://unsplash.com/photos/PMxT0XtQ--A

Tertiary users are those who interact with the primary user during the use of public transit. While they're heading to their destination, the primary user will have to interact with other pedestrians in a way that does not present discomfort or a lack of empathy for their personal space. Therefore, considerations will need to be factored into the design.

User Demographics

To find information about Last Mile Vehicle Riders, certain searches will need to be made to obtain a "look and feel" of the demographic of riders. This will assist in further demographic research.

Demographic Image Search

Figure 2-2-1 – Bird electric scooter riders in Santa Monica, California. Photo by Dan Tuffs of The Guardian

https://www.theguardian.com/cities/2018/apr/25/electric-scooters-urban-transport-bird-santa-monica-uk

Male + Female rider on rental Scooter (Bird). Not wearing helmets. Early to mid-20s. Using a cellphone while riding.

Figure 2-2-2 – Self-balancing unicycles at 'Paris sans Voiture' (Paris without cars), September 2015. Photo uncredited on Wikipedia

https://en.wikipedia.org/wiki/Electric_unicycle

Male + Female riders on Unicycles. Taken in France during "Paris without cars", a day encouraging the use of alternate modes of transportation. All riding the same vehicle (electric unicycles). In their mid to late 20s. One out of ten wearing a helmet

Figure 2-2-3 – Electric Bicycles lined up ready to be rented. Photo uncredited on Medium

https://medium.com/cityoftomorrow/lets-go-for-a-spin-ford-buys-scooter-company-to-provide-customers-a-first-last-mile-solution-bbeae278d373

Male commuter riding scooter past a row of public bikes. Rider in a bike lane. Using a helmet. Late 20s early 30s. Well dressed.

Figure 2-2-4 – LA Metro has approved the URB-E for use on Los Angeles public transport. Press photo by URB-E.

https://urb-e.com/blogs/news/la-metro-loves-urb-e-electric-scooters

Production shot for LMV company (URB-E). Both riding the same vehicle. Waiting at the metro stop

One user (male, mid-20s) has LMV folded. Another user (female, mid-20s) resting on a stationary vehicle

Figure 2-2-5 – Save yourself a few steps with electric transportation. Photo by Josh Miller for CNET.

https://www.cnet.com/news/electric-scooters-are-amazing-last-mile-transportation/

A group of students riding a variety of different transportation methods. Riders look as if they're in their late teens, early 20s. Riding scooters, "hoverboards", and an electric skateboard. One rider has a helmet

Age + Gender

Figure 2-3-1 –Woman riding Segway in an urban environment. Photo by Timur Romanov on Unsplash.

https://unsplash.com/photos/f1Hsmb4f5Z0

Overall, User Demographics for LMV tends to be an average of 32 years old split between men and women. The majority of which are middle class and have a high school education. Most images found regarding LMV riders involves younger users. This could reflect in the data observed as these methods of transportation are significantly less expensive than owning a vehicle.

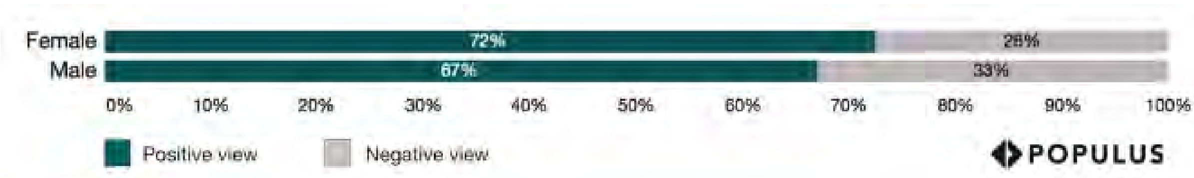


Figure 2-3-2 –Opinion of E-Scooters by Gender. (Micro, 2018).

As the average age of LMV rider is reported as 32, it can be deduced that this is a contributing factor to the "middle class" demographic trend that's observed. Obtaining a source from the Chinese market (Cherry, 2016), we can observe this user demographic among the two larger global markets. Most trips using LMV are to and from school and as short, inner-city commutes where a vehicle could have been taken but was opted out. "Between 2006 and 2012, gender is relatively evenly split, with some increase in the percentage of male respondents. The average age is about 32 years old." (Cherry, 2016)

Consistent with electric scooter adoption data, it was also noted that slightly more women have a positive view of electric scooters than men (see Figure 2-2-6). This early data on e-scooters provides evidence that newer, micro-mobility services might achieve greater gender parity than previous station-based bike-share systems have. (Micro, 2018).

Ethnicity

As the design solution for the thesis involves a form of readily available transportation found in various diverse cities, the barrier for entry and interest in the product has no bias towards specific ethnicities.

Education + Income

Year	Sample size	Individual characteristics				Household characteristics			
		% Male	Age	Monthly income (RMB)	% College degree	Yearly income (RMB)	Adults	Working adults	Child
2006	303	49	33.1 (9.6)	1930 (1165)	20	41,637 (27,337)	2.9 (1.1)	2.4 (1.1)	0.6 (0.6)
2008	597	52	32.5 (9.5)	2258 (1138)	31	66,190 (33,801)	3.1 (1.4)	2.4 (1.0)	0.6 (0.7)
2010	515	59	30.5 (10.2)	2535 (1395)	24	60,242 (34,879)	3.3 (1.5)	2.5 (1.2)	0.5 (0.6)
2012	801	57	31.7 (9.7)	2921 (1343)	23	67,937 (39,532)	3.1 (1.3)	2.4 (1.3)	0.6 (0.7)

1. Standard deviation in parenthesis.
2. Average Incomes are estimated from mid-points of income categories.
3. Primary Income Earner status is applied if individual contribution to the household income is greater than the average share of all working adults in the household.
4. Income questions refer to year previous of survey.
5. $1 = 8.00 RMB (2006), $1 = 6.80 RMB (2008), $1 = 6.75 RMB (2010), $1 = 6.30 (2012).

Figure 2-4-1 –Demographics of e-bike users. (Cherry, 2016).

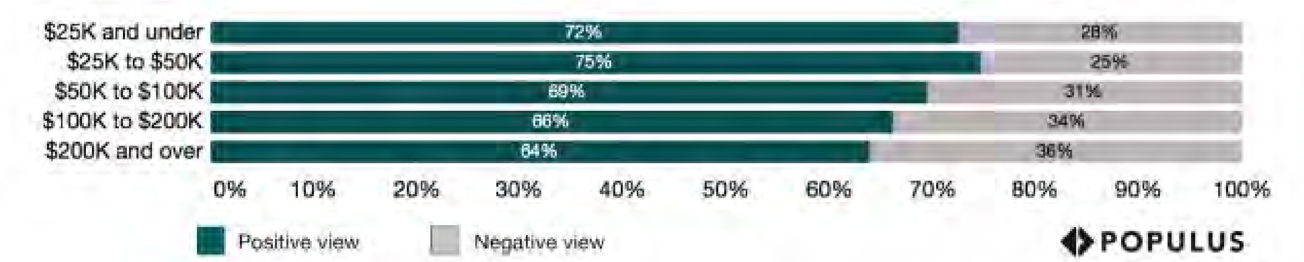


Figure 2-4-2 –Public perception of e-scooters by Income. (Measuring, 2018).

By observing Figure 2-4-1 and 2-4-2, it can be noted that:

- The average age of a Last Mile Vehicle rider is 32.
- They belong, on average, within the 'Middle Class' bracket
- 23% of riders have college degrees
- Reception is more positive among those earning $100k and under.

This is reflected in the "public" nature of the product, as these sorts of vehicles are designed to lower the bar of entry for those looking to adopt micro-mobility into their daily commute.

Demographics Summary

Overall, User Demographics for LMV tends to be an average of 32 years old, split between men and women. The majority of which are middle class and have a high school education. Most images found regarding LMV riders involves younger users. This could reflect in the data observed as these methods of transportation are significantly less expensive than owning a vehicle. As the average age of LMV rider is reported as 32, it can be assumed that this is a contributing factor to the "middle class" demographic trend that's observed. Obtaining a source from the Chinese market (Cherry, 2016) allowed user demographics to be analyzed between the two larger global markets for these vehicles (US and China).

Demographics of LMV Riders		Reference
Age	<32	(Lime, 2018) ; (Micro, 2018)
Gender	52% Men to 48% Women. Close to tied	(Cherry, 2016);(Lime, 2018);(Micro, 2018)
Ethnicity	Global adoption	(Micro, 2018);(Lime, 2018)
Educational Background	High school or college education	(Cherry, 2016)

Table 1 – *Summary of LMV Rider Demographics*

User Persona

Figure 2-5-1 Young adult with an electric longboard. Uncredited photo for the Vancouver Sun.

https://vancouversun.com/news/local-news/vancouver-mans-first-ride-on-electric-skateboard-ends-with-600-ticket

Name	Brian Zhao
Age	27
Job	Part-time retail + Content creator
Income	$50,000
Education	Ongoing, University for Computer Science
Relationship	Girlfriend
Location	Palo Alto, California
Hobbies	Youtube Content Creator, Photographer
Frequency of use	Between lectures, work, downtown
Social Activities	Friend group from work + University
Other interests	Fitness enthusiast, D&D group

Table 2 – *User Persona Profile*

Profile

Brian Zhao is a 27-year-old first-generation Chinese American. He was born in Palo Alto and currently lives with his parents while finishing his second undergraduate degree in Computer Science. He works Part-Time at the Apple Store at the nearby shopping center and has a relatively successful Vlog channel on YouTube. Cumulatively between jobs, he earns $50,000.

Brian uses a Boosted Board to commute around campus, go to work after class, and head downtown on Fridays and weekends where he meets up with friends to go for drinks at the local pub.

Brian's LMV Usage

Brian uses his Boosted Board as his primary source of transportation. If the commute is too far, Brian combines the use of his board with public transit or ride-sharing platforms like Uber or Lyft. He likes to get homework done in cafés off-campus and uses his board to go to nearby locations, using the establishment's Wi-Fi to stay connected and their outlets to charge his board. On longer trips to San Francisco, he rides his board to the train station to meet with his girlfriend. Once there, she rents a nearby bike and they ride to nearby parks.

Brian's relationship with his LMV

Brian bought his board second hand on Craigslist. This was initially as an inexpensive way to commute around campus but turned into a hobby. He enjoys riding it around campus, enjoying the closed off privacy that his University affords him. He has been able to successfully repair his board's components by himself and often goes to monthly meetups where he rides in a social group setting.

2.1.2 Current User Practice + Observation

To gain insight into existing user practices, a local LMV rider meetup was observed. I initially planned to interview a local LMV user on their day-to-day activities revolving around their commute. I posted several different requests on forums to no avail. A day later, I received an invitation to attend a Toronto Boosted Board social ride. Seeing this as an opportunity to get some insight on how the average user rides their LMV, I accepted the invitation and met up with the other riders in front of "Longboard Living", an independent skate shop based downtown. After charging our boards, I started speaking to a few of the regulars on the ride about their use cases, tips, and how general commuting was. During the ride, one of the attendees got into an accident as they lost control of their board when their remote encountered a glitch and delayed an input. This, along with other observations, is noted below.

Figure 2-6-1 Longboard rider meetup (I'm on the left!). Personal photo, Toronto Ontario.

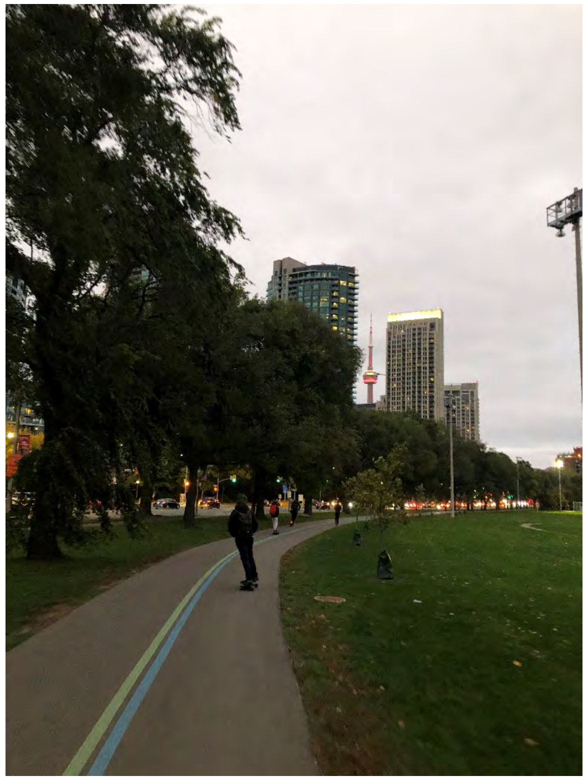


Figure 2-6-2 Evening longboard ride on the bike path by Toronto Waterfront. Personal photo, Toronto Ontario.

Throughout the ride, several observations and general inquiries were made regarding the rest of the group's commute experiences and their history of riding these vehicles:

- All 5 riders wore helmets
- 3 of the two rode Boosted Boards (recognized brand name).
- 2 of the 5 use their board as their ride to work, 3 use it for school
- Helmets were noted as "an essential" among all riders.
- Members of the community do not appreciate when riders are without one.
- 3 of the 5 riders used a personal sound-emitting device (whistle, beeper) to alert surrounding drivers of their presence.
- All riders used hand signals to alert drivers of their intention and the group of their route.

- No injuries were sustained during the ride.
- Minor technical glitch encountered with the user's Longboard (smaller OEM).
- Cellphone use was discouraged among all riders, relying on verbal cues to telegraph movement.
- One rider was observed carrying a smaller board in their backpack alongside their objects.
- The ride lasted 45 minutes with 15 minutes of socializing before departure.

Although this was a single riding experience, the frequency of this meetup, along with the general responses observed by the participants is an accurate description of a general group ride session.

2.1.3 Activity Mapping

Figure 2-7-1 User Experience Map & areas of potential improvement.

Observations

Based on the methods of observation, many new considerations can be made to determine the design direction for LMV safety improvements. By reviewing the factors that lead to an accident, and by experiencing riding alongside a group of riders entrenched in the community, it can be said with confidence that the improvement ideas shown in Figure 2-7-1 can be potentially applied to the system to improve rider safety.

The potential improved system consists of three parts. The first is a vehicle design that factors in many of the areas of frustration that users may have while commuting (alerting drivers + pedestrians to their presence, driving on unfamiliar terrain). The second is a pair of interactive Augmented Reality glasses that act as both protection to the user while reaching higher speeds, and as a system to notify them of their travel information. The third would be a form of a jacket which assists in notifying those around the rider of their presence, while also acting as a stylish preventative safety device. This can potentially involve an exoskeleton that prevents limb damage, padded neck and head protection that's contextual to the situation, and sensors that can detect which safety protocol to execute.

2.1.4 Ergonomics + Safety and health

Current micro-mobility devices vary across sizes, formats, and features. However, they all follow specific ergonomic needs to safely operate. User's currently must be 18 years old or over to legally operate private e-bike and scooter products (Lott, 2018). Users must also be able to safely throttle the speed and movement while operating.

Since there are a variety of products out there which require different ergonomic considerations, a list of ergonomic requirements was produced:

- Ability to safely adjust speed, merge with moving traffic
- Ability to signal to other motorists and riders your movement intentions
- Ability to stand comfortably for the duration of the ride
- Ability to quickly dismount in the case of a potential accident
- Ability to make quick observations and decisions while operating

As the nature of this design solution revolves around the improvement of safety for LMV riders, there is a need for a comprehensive focus on the health and wellbeing of the rider as well as those around them. Although space is being shared with conventional vehicles, there is a lack of proper regulation and enforceable safety standards when purchasing and operating an LMV. Although some countries have laws that require riders to wear a helmet during the operation of their vehicle, diverse micro-mobility form factors and different hardware has grown faster and have been adopted by commuters quicker than these laws could be put in place. Many of the regulations have been enforced by their respective communities, although not in any official manner. Safety and Health concerns for LMV riders share similarities with those who ride other single-passenger vehicles. This includes but is not limited to;

- Head + Neck protection.
- Arm and knee guards.
- “Dead Man’s Switch” (emergency cutoff).
- Limb protection.
- Ability to signal movement intentions to other riders.
- Ability to telegraph reduction in speed.

Although many products currently exist that will fulfill this need, the industry has yet to adopt this sort of technology for higher speed collisions, as well as factoring in the possibility of integrating some form of preventative safety technology to decrease the possibility of injury.

2.2 Product Research

2.2.1 Current Products

Product Benchmark

To gain a better understanding of the design solution, it is important to benchmark existing products. As the solution consists of a system of hardware working in unison, a pool of existing products was gathered and compared, each sorted into their categories:

- Vehicles: Examples of existing consumer-ready LMV
- Heads Up Display: A variety of HUD products that display information to users
- Safety equipment: Diverse examples of existing safety product

Product Type	Name	Description	Specifications
LMV	Xiaomi Mi Electric Scooter Pro	Electric Scooter	Built-in braking system with brake lights
	Ninebot S-PRO by Segway	Self-Balancing solo vehicle	Follows users, stable, turn signals
	OneWheel XR	Single Wheel all-terrain vehicle	The large wheel provides all-terrain access.
HUD	Google Glass (Enterprise Edition 2)	Industry grade Augmented Reality lenses	Projects content within wearers peripheral vision
	Vuzix Blade	Consumer-grade Augmented Reality Lenses	Provides notifications and at-a-glance info
	Microsoft HoloLens 2	All-In-One Augmented Reality headset	Can project digital content over physical environments
Safety Gear	Google Jacquard	Jean jacket for commuters	Smart sleeve fabric accepts user input
	Helite TOURING Airbag Jacket	LMV or motorbike jacket	Built-in airbags that deploy in case of an accident
	CrossHelmet	Smart Helmet	Rear-view camera and ability to accept calls

Table 3 – *Product Benchmarking*

Product Benchmark

Based on the information obtained from the prior benchmark, the existing products can be plotted along with an X-Y graph. This will reveal potential product opportunities to be explored as well as provide insight into what current product trends are. The information will be plotted along two axes:

- X: Benefitting the Primary User (Rider) vs Secondary Users (vehicles)
- Y: Active (user input) vs Passive (automated)

Last Mile Vehicles

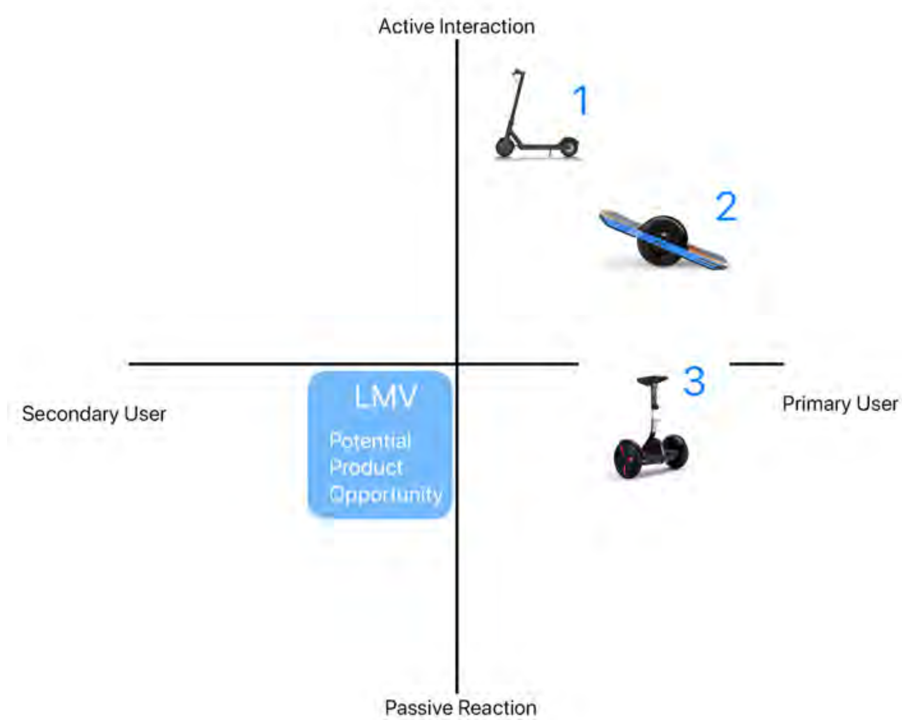


Figure 2-8-1 X-Y Comparison of existing Last Mile Vehicles

1- Xiaomi Mi Electric Scooter Pro - https://www.amazon.com/Xiaomi-Electric-Long-range-Fold-n-Carry-Ultra-Lightweight/dp/B076KKX4BC
2- Ninebot by Segway S-PRO - https://store.segway.com/ninebot-by-segway-s-pro
3- OneWheel XR - https://onewheel.com/products/xr

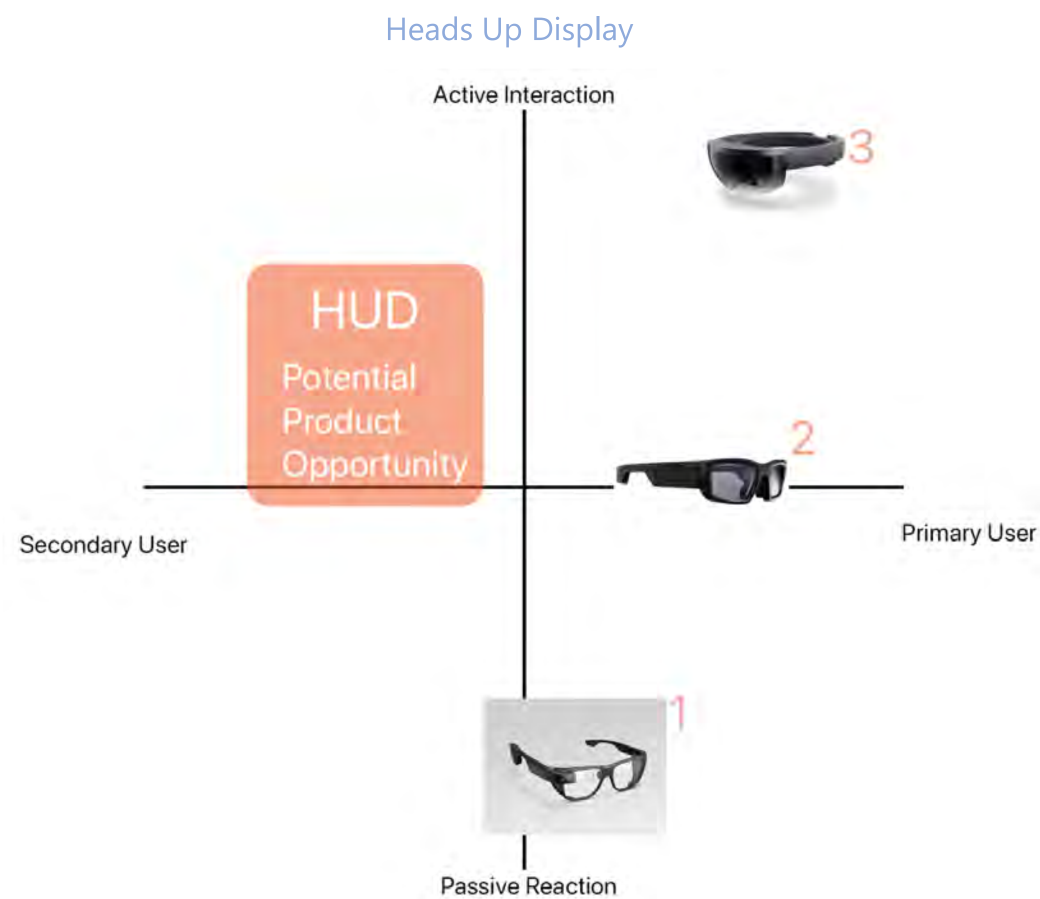


Figure 2-8-2 X-Y Comparison of existing Heads Up Displays

1- Google Glass Enterprise Edition 2 - https://www.google.ca/glass/start/

2- Vuzix Blade - https://www.vuzix.com/products/blade-smart-glasses

3- Microsoft HoloLens 2 - https://www.microsoft.com/en-us/hololens/hardware

Safety Equipment

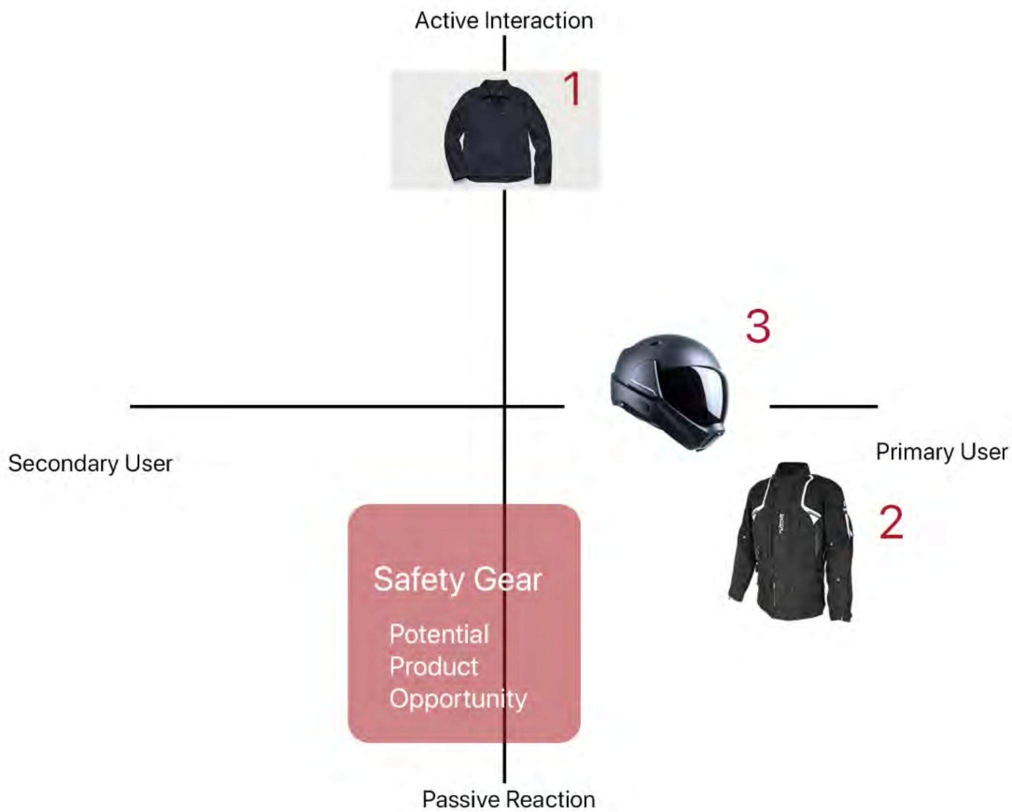


Figure 2-8-3 X-Y Comparison of existing Safety Gear

1- Google Jacquard - https://atap.google.com/jacquard/
2- Helite TOURING Airbag Jacket- https://www.helite.com/touring-grey-adv-rider-jacket-airbag
3- CrossHelmet - https://www.kickstarter.com/projects/491835187/crosshelmet-the-smart-motorcycle-helmet

The products that were chosen to benchmark all have specific benefits and features that could be viable as a thesis solution. Although there are three separate products in this system, there are many attributes that are shared between the three. They will be listed in a table below.

Features	Benefits
Turn signals + Brake Lights	Secondary User Safety
All-terrain navigation	User Flexibility
Preventative safety measures	User Safety
Contextual alerts + Notifications	User Experience
Portable	User Comfort

Table 4 – *Features + Benefits for LMV operation*

2.2.2 Benchmarking Functionality

The overall system is built to achieve a single goal; ensuring the safety of the rider. Although three distinct products, they all contain similar aspects that lend themselves to the needs that they satisfy. Although not as fast or as private as a standard automobile, these forms of transportation allow for different benefits over these conventional means. The portability and ease of deployment of these LMV allow them to be more flexible as an urban commuting option; granting users free range to merge between bike paths and the road, allowing them to be used alongside both bikes and cars, and the ability to dismount and roam without the need to find a parking spot.

The following lists focus on the key functions of each product line; Vehicle, Protection, and HUD technology. This information is derived from observations taken during the group ride.

Vehicle findings:

- Although the price is factored into the decision of a vehicle brand, prior user experience, reviews, and manufacturing standards sway the purchasing power.

- Portability is a must to safely and efficiently transport your LMV on and off public transit.
- Being able to alert drivers and pedestrians to your presence is important. Both actively (bell, noisemaker), and passively (Turn Signals, Lights).

Protection Findings:

- Current means of protection are not adequate for high-speed impacts, collisions, or falls. They are built to protect the most vulnerable parts of the body (Head, Elbows, Knees).
- Current protection is often bulky and cumbersome to wear, having users either hindered by their use or opt-out of using them entirely due to inconvenience and discomfort. Safety gear is often only used for longer rides.
- Smart materials are not yet widely adopted; however, they are used to provide input in some use cases. Contextual cues and information can potentially be given by the rider with minimal discomfort.

HUD Findings:

- Heads Up Displays often offload computational power to a remote processing unit. This allows them to be designed to receive + project information; thus, keeping them light and comfortable for the wearer.
- Information is often projected onto a small surface area. This means that the majority of practical and nondistracting uses involve key information being displayed off to the side.
- Interaction with the content on the screen can be based on external sensors and machine learning (recognizing objects and displaying appropriate

information), or it can be from the user (speaking to a virtual assistant, swiping a touch-sensitive pad).

Given this information, decisions that factor into the final design solution can be implemented.

2.2.3 Benchmarking – Aesthetics & Semantic Profile

Overall Aesthetics

Styles and trends change the look and feel of personal electronics, and this product solution is no exception. Last Mile Vehicles don't have a distinct look or feel since there is a multitude of different form factors that can be interacted with by the user. There is a fine line between ruggedness and a sleek, portable design. To maintain a cost-effective vehicle while also offering a sense of luxury, steps will need to be taken to preserve a delicate and attractive chassis. Another challenge comes from the design of the family of products; the glasses and the safety equipment must complement each other, as well as the vehicle's design language.

Figure 2-9-1 + 2-9-2 Segway Design Language. Press photos by Segway

Segway Loomo - http://www.theharbingerchina.com/blog/introducing-loomo-when-mobility-meets-ai-with-segway-robotics-president-li-pu

Segway E+- https://avvenice.com/en/drones-hoverboard/3244-segway-ninebot-by-segway-e-black-hoverboard-self-balanced-robot-electric-wheels.html

Contemporary designs must be analyzed for their functionality, as well as their overall tone and aesthetic.

The HUD can take many forms, from a nondescript yet feature-packed pair of glasses to an attractive, large glass visor. Whatever the decision is, weight and comfort are of a top priority. A tactile feel, be it from haptics or a bone conducting headset, will assist in the rider’s safety during the operation of the vehicle.

The safety equipment, whatever the final design direction is, will need to have a tactile and sturdy feel without becoming a hindrance to the rider. However, as is often the case with these sorts of peripherals, the lighter they feel, the less protective they appear.

The overall system would benefit from a cohesive design language that encourages interaction while also stylistically blending in with whatever apparel the rider is wearing.

2.2.4 Benchmarking – Materials & Manufacturing

Material and manufacturing needs differ based on the peripheral. As there are three components to the thesis solution, each product will be discussed separately.

Vehicles

Of all three of the product lines that are being discussed, the LMV is the most complex in terms of design and material usage, having to factor in regulatory decisions that will shape the build of the final vehicle. It faces the challenge of having to be durable enough to ride in the street, yet light enough to carry on to public transit and to store. The components that will be required would be:

- The motor & motor housing

- Tires
- Chassis
- Battery
- Storage bag
- Lighting system
- Computational system

Further research will need to be conducted to gain a better understanding of the materials that will ultimately be used in the final design of the vehicle.

Safety Equipment

Being one of the two wearable components of the system, the product that protects the user from an accident or fall must be light enough to wear without obstructing or inconveniencing the rider. Based on the current direction, components for the safety peripheral will be:

- Padded cushioning on the inside of the product
- A fastening system that will help keep the product aligned
- An airbag system that is deployed when an accident is detected
- The computing system that detects the accident
- Indicator LEDs to alert other riders and drivers of the user’s intents.

Further research and styling will need to go into the design of this component and this section will be updated once a final design direction is chosen.

HUD

Since this is the device that will be the most intimately attached to the user, the HUD needs to be lightweight while also containing an adequate onboard battery to operate at an extended period. Major components of the Heads-Up Display include:

- Refractive prism to project light onto the lens
- Lens to act as a viewfinder for user
- Glass to assist with vision at higher speed
- Input method to control settings (microphone, touch)
- The computational power required to operate
- Cameras and sensors to assist in special awareness
- Projector

These components are dependent on the final design direction.

2.2.5 Benchmarking – Sustainability

The following section is included to discuss the sustainable actions that are factored into the environmental importance of LMV operation and how each benchmarked product classification can assist in offering an environmentally sustainable solution.

Seeing as LMV operation is already considered a more environmentally conscious decision, it is safe to say that the equipment that goes along with it must also share the same message. Last Mile Vehicles, much like conventional vehicles, are designed to be repaired as components fail. However, due to the stripped-down nature of these micro-mobility options, components are easier to replace and often don’t require input from the original manufacturer (safe for defects in manufacturing or software). This already poses a large environmentally sustainable opportunity that can be factored into the vehicle design; simple to replace components that require minimal effort to repair.

Where the waste is generated, however, is in the disposable nature of the safety equipment. Helmets and kneepads are designed to sustain a single impact than are rendered ineffective by the damage wrought to them. This wasteful practice, although lifesaving, can impact the environmental consciousness of the design at hand. By implementing a replicable, modular safety system, users do not have to worry about wasting materials should they encounter an accident.

Although indirectly impacting the sustainability of the product system, the HUD, as well as any form of preventative safety measure, can lower the chances of equipment damage, lengthening the life of the products.

3 Analysis

In this chapter, products that were benchmarked in the previous chapter will be analyzed. Based on the primary users' needs, the functionality, usability, aesthetics, and sustainability of the system solution will be established. This work will culminate in a design brief for the proposed thesis solution

3.1 Needs Analysis

Contemporary LMV solutions aim to provide users with a variety of "dependent" needs. That is to say, the wide range of form factors aim to fulfill unique needs. Products with a focus on user comfort, safety, and portability often prove to be more successful in terms of adoption, as can be seen with the wide variety of scooter rental services found in metropolitan areas. This need extends to the usage of safety equipment worn by the rider. Traits that are common amongst all three products in the system will lead to an overall safer commute for the operator, and those around them. By improving visibility (of both the rider, and their intended movement), ride comfort, and portability of the current system, the proposed design system will be successful.

3.1.1 Needs/ Benefits Not Met by Current Products.

As mentioned in the previous chapter, the improved speed and power of current micro-mobility vehicles have currently outpaced the effectiveness of older methods of safety. Since the price of necessary hardware (LEDs, processors, batteries) has decreased dramatically in the past decade, many companies have entered the safety game. However, no breakthrough has dramatically disrupted the industry. This can be associated with the lack of a dedicated platform or use case for these kinds of vehicles. A lack of standardization. The following table addresses specific needs and potential improvements involving the operation of Last Mile Vehicles.

Needs	Improvements
Comfort	- Gifts users with a sense of pride due to environmental impact - Ride for extended periods
Portability	- Provides a sense of freedom when navigating an urban environment - Becomes less of a burden for the user to carry along with them
Information	- Provide at-a-glance contextual information to increase safety - Telegraph intended movement to nearby vehicles - Identify potential hazards during a commute
User Experience	- Users interact with a series of diverse products in a shared ecosystem. - Less time spent in traffic, more flexibility to explore an urban environment

Table 5 – *Needs + Potential Improvements in the proposed Design Solution*

3.1.2 Latent Needs

Needs	Fundamental Human Need	Relationship with Benefit
Comfort	- Physiological - Safety - Esteem	Strong
Portability	- Physiological - Esteem	Moderate
Information	- Safety - Esteem - Belongingness - Self-Actualization	Strong
User Experience	- Safety - Esteem - Self-Actualization	Strong

Table 6 – *Benefit Relationship*

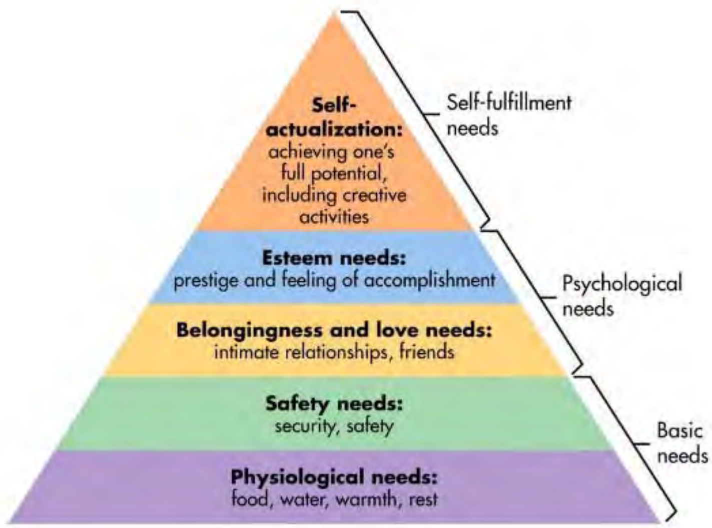


Figure 3 - 1 – *Maslow's Hierarchy of Needs*

3.1.3 Categorization of Needs

Wishes/Wants

- The product that can be easily transported
- Attractive, sleek, and light design
- Robust features and connectivity

Immediate Needs

- Easy to mount and dismount quickly
- Easy to transport onto and off public transport
- Weatherproofed design

Latent Needs

- Easy to repair and modify components
- Easy to ride and interact with
- Clean, modern aesthetic
- Holds a charge and is easy to ride

3.1.4 Needs analysis diagram

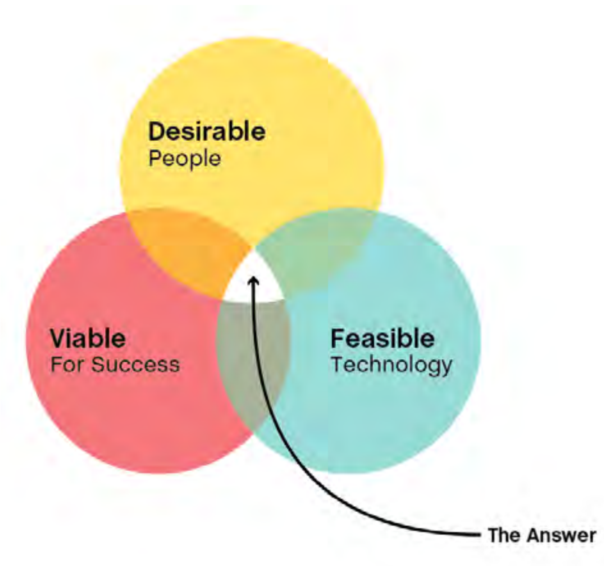


Figure 3-2 – *IDEO's Needs Analysis Diagram*

Desirability

As more people become conscious about their contributions to urban traffic and pollution, less are looking to purchase traditional vehicles, instead opting to purchase LMV as an alternative. By tempting prospective users with lower fees, more flexible traversal, and an ultimately healthier choice for the rider and the planet. By making these vehicles as diverse as possible, different users can purchase a micro-mobility vehicle that suits their preferred ride style.

Viability

Although there is a wide adoption effort into sharable and private LMV, many places have been hesitant to allow them to legally share the road with cars. Areas with extreme weather conditions will also impact the ability to readily rely on it as a consistent mode of transportation.

Feasibility

Traffic in urban areas creates a plethora of problems. The economic cost in major cities like New York can reach upwards of $33 billion per year. Congestion can impact the standard of living, even for those who are not commuting; raising the noise and pollution levels in urban spaces. The use of Autonomous Vehicles, at least when it's not used as a form of public transit. Technologies including Last Mile Vehicles (LMV) and ridesharing programs have been shown to reduce the number of vehicles on the road, but without any set system in place, it will be hard to scale.

3.2 Functionality

3.2.1 Activity Workflow Mapping

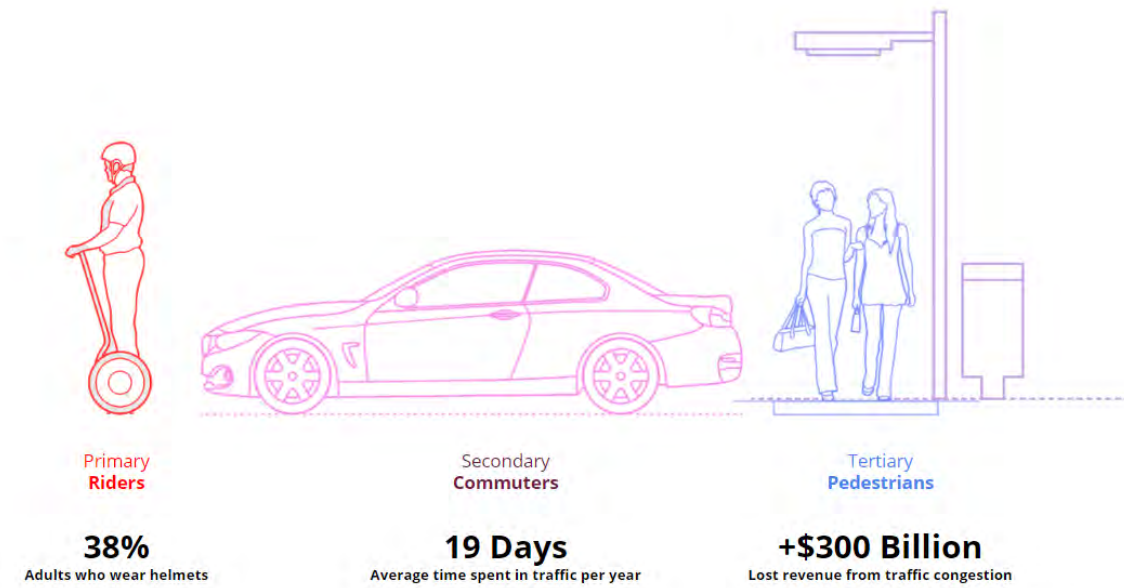


Figure 3 - 3 – *Primary, Secondary, and Tertiary users + Relevant information*

The objective of this section is to conduct a series of observations to generate a 'user experience map' from which design considerations may be drawn. These observations come in the form of in-depth video analysis and observing common scenarios that would be experienced by riders

This observation takes the form of a video analysis of a 'vlogger' recounting a high-speed accident that occurred while operating their vehicle (an electric skateboard

The preliminary search query used to find the video was "Boosted board accident" on YouTube. The reason 'Boosted Inc.' was used during the search was to increase my chances of finding a better-produced video. The term "Boosted Board" has become a popular synecdoche for these Last Mile Vehicle form factors, so the odds of a relevant video being posted were increased. The video that I decided to choose to analyze was posted by 'JohnPaulYT' on the 20th of June 2019 and has at the time of writing over 23,500 views. The contents of this 13-minute video involved a recounting of a recorded incident the rider encountered which led to a severe injury. The context for the video can be summed up by its description:

"If you ride an electric vehicle, you WILL crash. It is inevitable. I crashed at 30 mph on a brand new Metroboard X. In this video, I review all aspects of my crash so others can hopefully avoid doing the same thing. I took some precautions and wore basic safety gear, but I have since upgraded my gear and changed my approach as a result of this high-speed crash."

Although the rider wore safety gear, they were still injured, and ultimately have changed their approach as well as some precautions for future excursions.

Video Analysis

To analyses the video, I am using the below chart to produce steps through the video while marking the pain-pleasure points of each part of the overall task. This is then plugged into a graph that will visualize the trends observed in the video. The data for "Potential Improvement" of the situation sits at a '3' on the provided scale as a solution would ideally negate many of the negative attributes associated with crashes or injuries caused by the terrain and the rider.

Video Title: '30 mph CRASH on a $2,500 Electric Skateboard, Destroyed iPhone – (Close Up Footage)		
Video source: https://youtu.be/pYKt6t6wKqk?t=310		
Timestamp: 5:10 To 8:23		
Task: Observe the steps and conditions that lead to a crash		
Step #	**Description**	**Gradient Scale of Pain – Pleasure Points** Negative = 1; Neutral = 3; Positive = 5 **1 2 3 4 5**
01	5:16 – Board becomes unstable due to speed	

		○	○	⦿	○	○
02	5:19 – Uneven ground which is difficult to identify while riding	○	○	⦿	○	○
03	5:41 – Uneven board adjusts rider’s direction without their input	○	⦿	○	○	○
04	5:47 – Manhole cover leads to wheel “getting air”, throwing off the rider's balance	○	○	⦿	○	○
05	6:05 – Rider’s direction changes rapidly, causing them to fall off the vehicle	⦿	○	○	○	○
06	6:25 – Rider remarks that their phone has been launched from their hand. Possible distraction.	○	⦿	○	○	○
07	6:40 – Rider lands on their hip which led to severe bruising	⦿	○	○	○	○

08	7:01 - Brunt of the blow on the hip	○	⦿	○	○	○
09	7:15 – User describes distance traveled while being projected from the board.	○	⦿	○	○	○
10	7:38 – 'Road rash' on leg due to a rider wearing shorts + no safety guards	○	⦿	○	○	○
11	7:55 – Sliding on the ground due to momentum	⦿	○	○	○	○
12	8:05 – Dislocated their shoulder by landing awkwardly on it and sliding	⦿	○	○	○	○

Table 7 – *Video analysis ranking table, ranking the 'steps' shown of the observed video.*

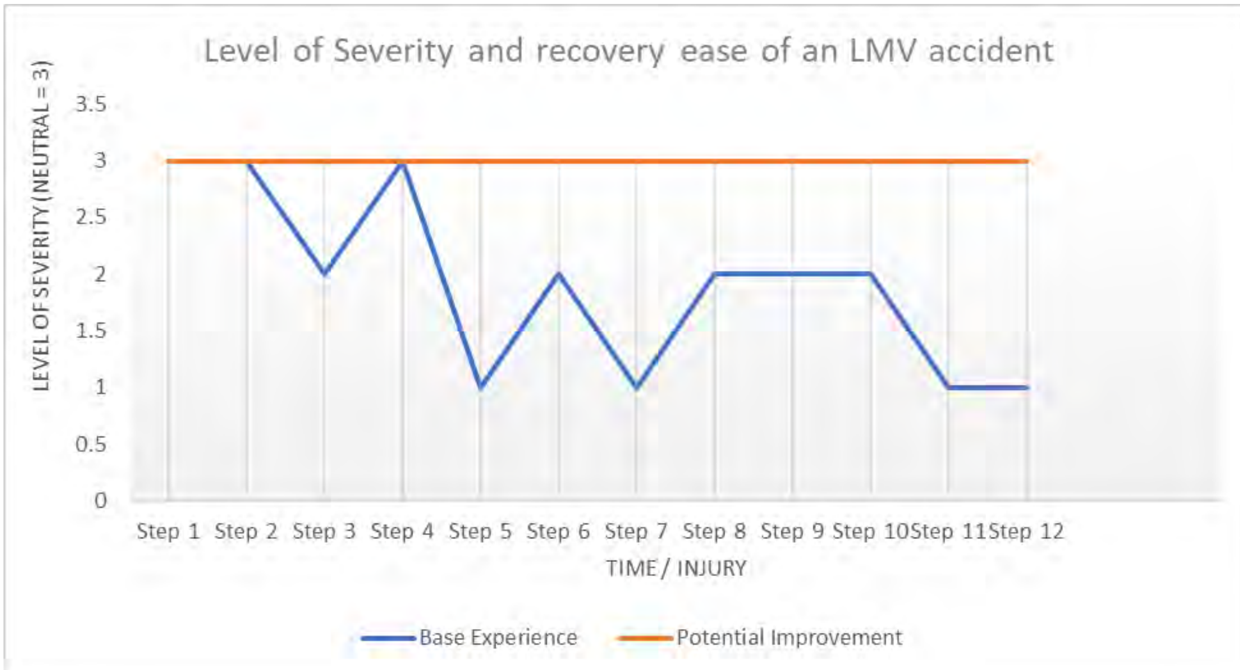


Figure 3 - 4 –*Chart displaying the level of severity of the 'steps' listed in the video segment*

As the graph shows, there is a sharp decline in the rider's comfort level as the prospect of injury enters the picture. As doubt in the equipment and the environment increases, so does the risk of injury. A potential area of improvement is to detect these instances earlier and constructively alert the rider; granting them a larger window to react.

3.2.2 Activity Experience Mapping

When operating a Last Mile Vehicle traveling from point A to B, there are four potential outcomes as illustrated in Figure 3-5. It can be observed as:

- Arriving at the destination after sustaining an injury
- Requiring medical attention after encountering a major accident

- Using the streets and bike lanes to arrive at your destination

- Using short public rides and public transit to arrive at your destination

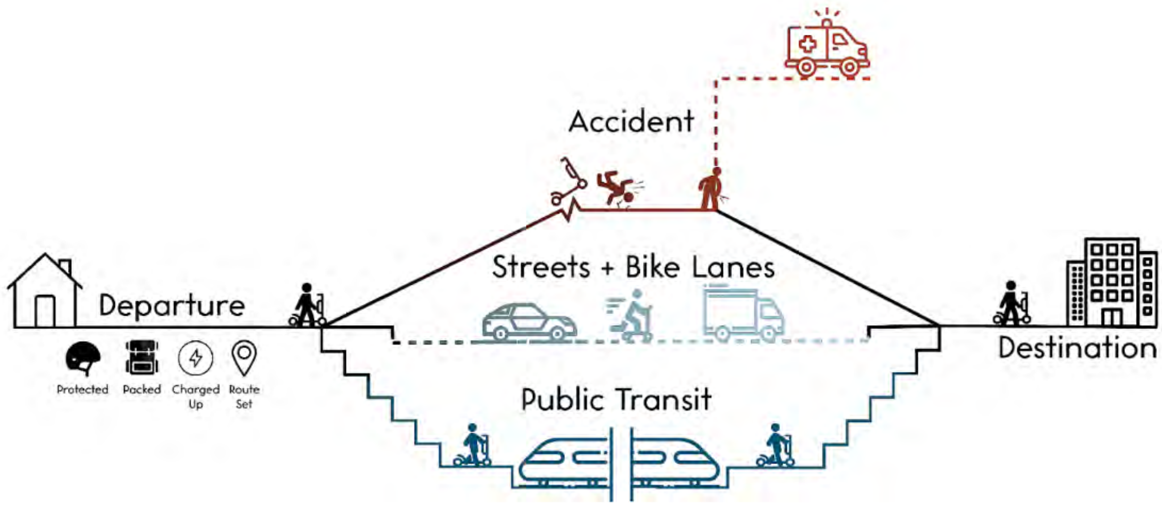


Figure 3 - 5 –*Illustration displaying the different potential outcomes of an LMV journey from point A to B.*

Accident

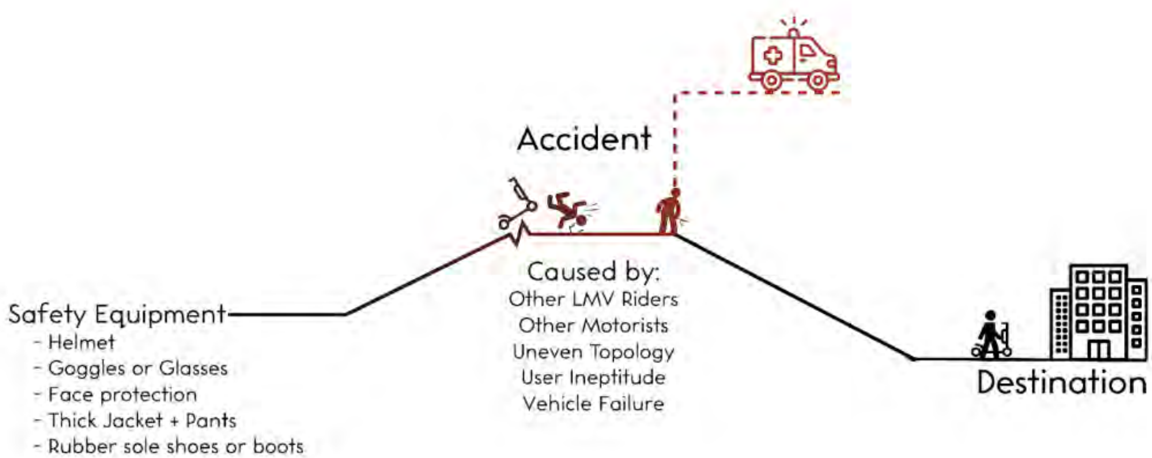


Figure 3 – 5 - 1 –*Illustration of the route and causes that lead to accidents and/or medical help.*

Riders will eventually encounter an accident while riding. It's inevitable, but it is possible to be prepared to prevent serious injury. As listed above in Figure 3-5-1, safety equipment is essential, but an unregulated aspect of micro-mobility. By incorporating many of these features into the design of the equipment, injury is reduced, even should the rider decides against protection.

Streets + Bike Lanes

Figure 3 – 5 - 2 –*Illustration displaying the potential benefits of an LMV journey from point A to B using roads.*

Riders who travel along streets and bike lanes will encounter several hazards as shown in Figure 3-5-2. While many of these factors can be detected while riding, there is still a risk of the user not reacting appropriately, or with poor timing. By removing most of the guesswork from the user, and allowing for an autonomous override, a potential solution can be implemented. The illustration above also lists many of the benefits found from these personal means of transportation; improving life within urban environments.

Public Transit

Figure 3 – 5 - 3 –*Illustration displaying the potential benefits of an LMV journey from point A to B using public transit.*

One of the appeals of LMV use involves the complementary interaction between the independent vehicle and existing commuter infrastructure. The portability factor of the design is essential as it needs to be able to be easily transported with the user.

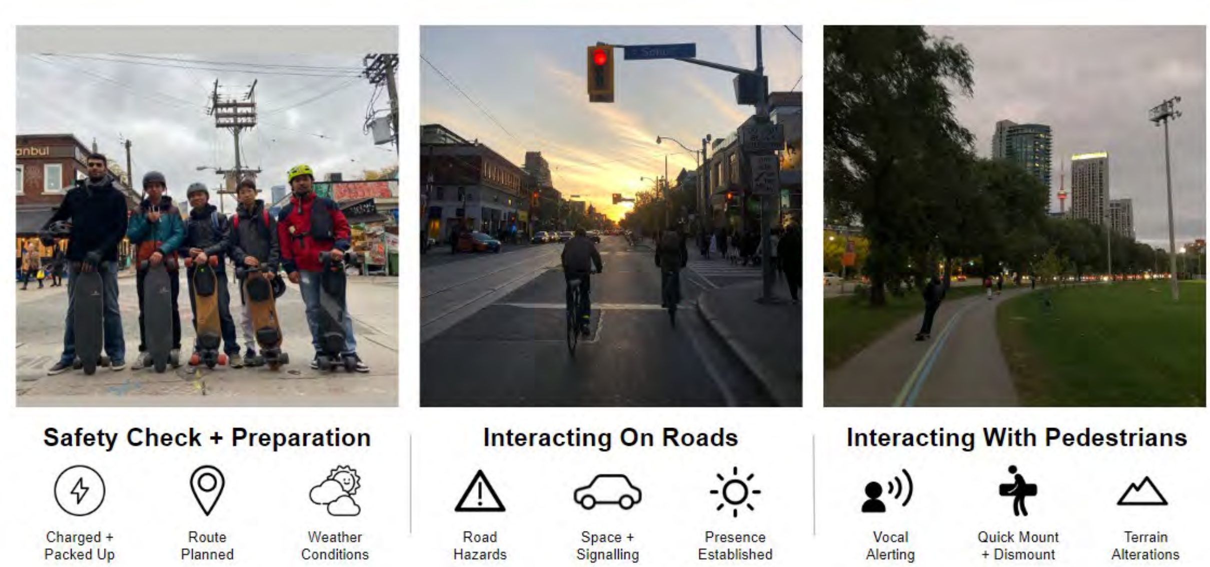


Figure 3 – 5 - 3 – *Essential Points of interaction with primary, secondary, and tertiary users*

3.3 Usability - Ergonomics

The following section of the report investigates the ergonomic requirements of the Last Mile Vehicle.

3.3.1 Introduction

Figure 3 – 6 - 1 A promotional image of the Segway S Pod Vehicle.
https://www.caranddriver.com/news/a30398345/segway-s-pod-scooter-revealed/

Although it is viewed as a relatively new industry, the idea of alternative urban commuting vehicles has been around since the advent of the bicycle. As the cost of electronic components continues to lower for both manufacturer and consumer, there has been a mad dash to properly solve the "Last Mile" of the trip for city travelers. These personal, single rider vehicles come in a wide variety of shapes and sizes to match the operator's needs, however, there has yet to be a massive push to improve the safety of the occupant, surrounding motorists that share the roadway, and pedestrians. To improve existing systems, and to further explore the potential future of this environmentally and more efficient mode of inner-city transport, an ergonomic model was constructed to observe user interaction, comfort, and overall ability to effectively use a system that consists of a vehicle, safety harness, and a form of head-worn protection.

3.3.2 Literature Review

Last Mile Vehicles (LMV) are currently seen as a niche product used in specific cases. However, their presence has begun to be incorporated into urban planning; from dedicated lanes to accommodations such as charging stations and parking enclosures.

The primary design solution is to improve the safety of the vehicle rider, as well as creating a cohesive and synergetic system that improves the user's overall riding experience and eliminates many of the current fears and anxieties faced during a short, 'last mile' commute.

The potential to innovate on current safety apparatuses and user interaction points has yet to fully be embraced. By using innovative and experimental materials and technology in tangent with a creative design direction, a family of products can be developed into an overall solution. To better understand the interactive nature of the product with potential users, a full scale 1:1 model of the system was created with the intent that this series of products will be used by commuters throughout their day; from commuting on city streets to being used in tangent with public transit.

3.3.3 Methodology

The purpose of this report and the resulting exercises was to accurately observe the ergonomic and full-bodied human interaction factors associated with the proposed system design for a Last Mile Vehicle commuter.

As the requirements for the thesis project involves three major body part areas interacting with the user, three independent products are being considered for design. This ergonomic report and evaluation will discuss the methods used to identify the specific needs of the user; from both a human factor and a convenience standpoint.

Challenges surrounding the ease and comfort of mounting, dismounting, and transporting the vehicle were also addressed throughout.

Interaction decisions

To better understand the needs of the user and to maximize comfort while interacting with the system, specific actions and considerations were taken:

- The ease of operation and mounting/ dismounting the vehicle (Arms, Legs).
- Comfort and mobility while wearing the safety harness and Heads Up Display (Head, Neck, Torso, Hand)
- Interacting with the system as a whole (hand, arms, UI/UX)

Potential user description

Due to the nature of this product system, the 1:1 scale mockup was designed to be used by:

- A target demographic consisting of existing urban commuters currently using alternative modes of transportation.
- Both male and female riders between the ages of 18 – 65
- Riders who can stand comfortably for shorter commutes (15 – 30 minutes)

Evaluation process

The evaluation process involved the users to interact with the scale model of the vehicle, safety harness, and heads-up display. While the vehicle model was designed out of base materials, similar-sized, existing products were used as a reference for specific interaction points of contact. These mockups include:

- Nintendo branded “Nunchuck” controllers to simulate the ergonomic grips of the vehicle’s control module.

- Oculus branded “Oculus Go” VR set to simulate the size and weight distribution of an ‘all in one’ Heads Up Display.
- ‘Incase’ branded backpack to simulate the vehicle storage and the straps of the safety harness

These placeholder products were chosen due to their similarities with the intended final design and as an easy reference for users to fully understand the intention and haptics of the products in the system.

Observation and environment study.

For this study, a 1:1 scale model of the proposed vehicle design was presented to users alongside the other products in the design solution, they were then asked to perform certain actions including:

- Mounting and dismounting the vehicle
- Putting on the ‘safety harness’
- Interacting with the vehicle's controls while mounted
- Interacting with the vehicle while dismounted (pulling, accessing the storage)
- Equipping and removing the Heads-Up Display

Location of study

Date of Observation: December 28. 2019

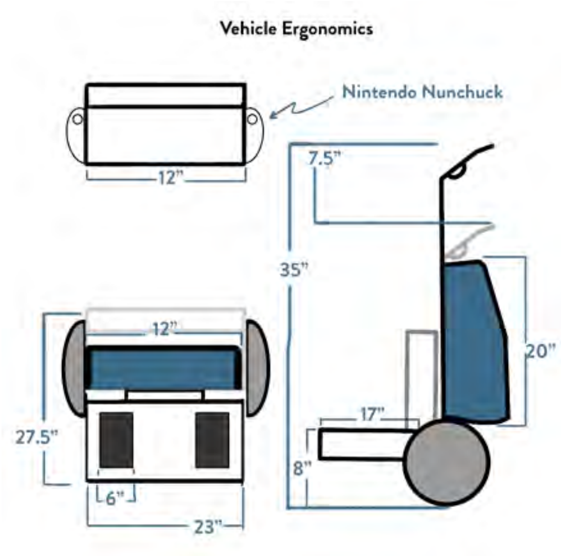
Location of Observation: Basement of domicile (Richmond Hill, Ontario)

3.3.4 Results

Measurements

Body Part/Person	**Sabrina (5%)**	**Larissa (75%)**	**Arman (100%)**
Foot length	10.5″	10.5″	12″
Foot width	4.5″	4″	5.5″
Shoulder to elbow	13″	12″	16″
Elbow to hand	16″	17″	20″
Face width	5.5″	5.75″	7″
Face height	7″	6″	9.5″
Height	5'4"	5'8"	6'6"

Table 8 – *Measurement table of participants including their name, percentile, and measurements*



*The body of the Nunchuk is 113 mm (4.4 in) long, 38 mm (1.5 in) wide, and 37 mm (1.5 in) thick. (Nintendo, 2006))

Figure 3 – 6 - 2 **Dimensions of the 1:1 scale rig designed to be interacted with**

5% female (Sabrina)

Figure 3 – 6 - 3 **5 %tile user interacting with 1:1 scale model of Vehicle + Accessories**

75% female (Larissa)

Figure 3 – 6 - 3 75%tile user interacting with 1:1 scale model of Vehicle + Accessories

95% male (Arman)

Figure 3 – 6 - 3 95 %tile user interacting with 1:1 scale model of Vehicle + Accessories

Interaction Illustrations

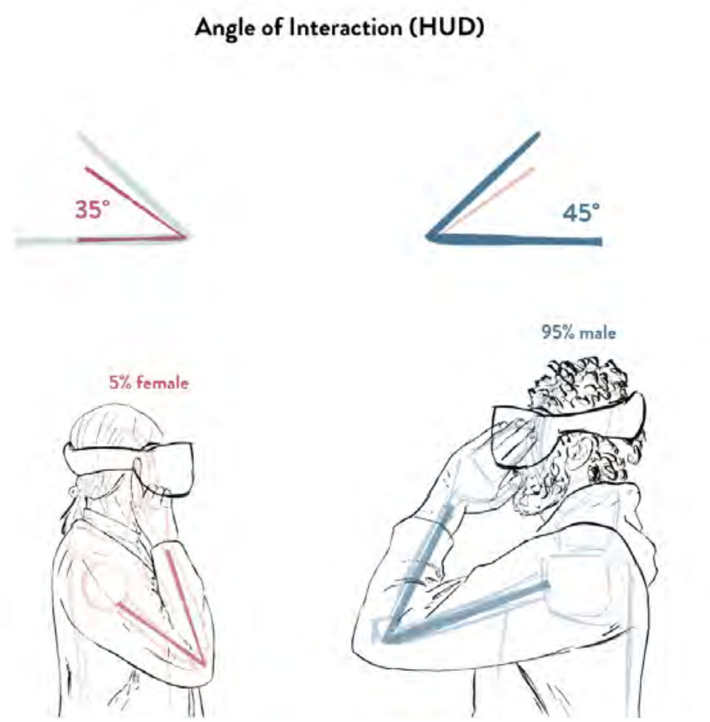


Figure 3 – 6 - 4 **Measured angle of interaction with the HUD visor concept**

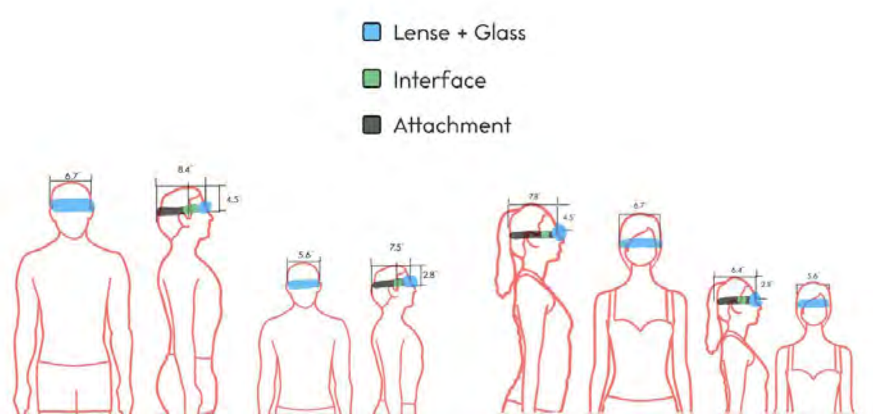


Figure 3 – 6 - 5 **Measured angle of interaction with the HUD visor concept**

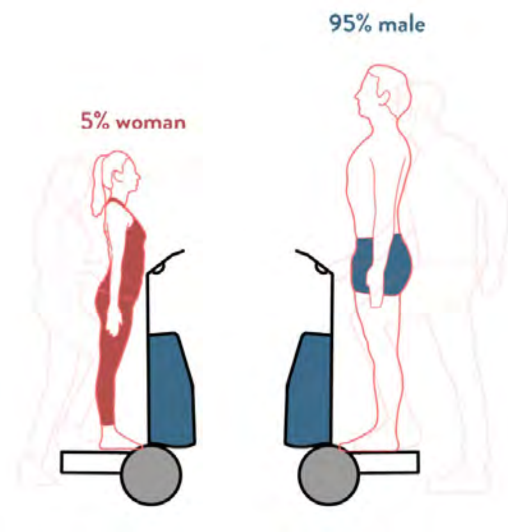


Figure 3 – 6 - 6 **Height relativity between 5 %tile women and 95 %tile man**

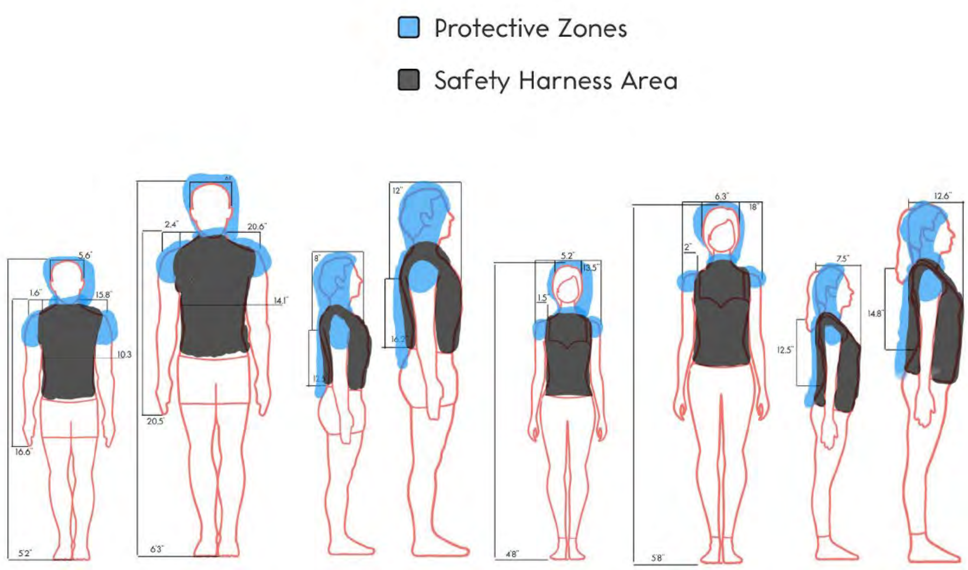


Figure 3 – 6 - 7 **Safety harness ergonomic considerations.**

3.3.5 Analysis

Figure 3 – 6 - 8 **A promotional image of the Segway S Pod Vehicle.**
https://www.caranddriver.com/news/a30398345/segway-s-pod-scooter-revealed/

Since each rider has unique preferences and tastes, it was important to build an experience that would be as accommodating as possible. The size and layout of the main vehicle input were spaced out by a foot due to the ergonomic comfort level of it across the different percentiles. It was noted that each subject agreed that the distance of the controller was comfortable and required little discomfort to use. Their position below the rider's heart was chosen to avoid arm strain after extended use. Since the vehicle was also designed to be used in tangent with public transit, the platform was designed to fold in when not in use. The height of 8" off the ground was found to be a comfortable enough height to avoid any form of discomfort when mounting/ dismounting the vehicle. This also increased the clearance of obstacles and changes in elevation while commuters are on the road. The collapsible controller module allows users to "drag" the vehicle when not in use (akin to small carryon luggage). This was a feature that was interesting to implement, as each user gripped the vehicle the same way when simulating dragging. The space for the user's feet was designed to increase the rider's stability by including pads to assist in users finding their balance and increasing traction. This decision helped center the user and make them more comfortable to ride the vehicle. This vehicle, although similar to the now recently announced Segway S-Pod (featured above), requires the user to stand as they operate it, therefore rendering this as a different class of vehicle. The largest similarity to the vehicle is self-balancing technology, which has improved dramatically over the past few years.

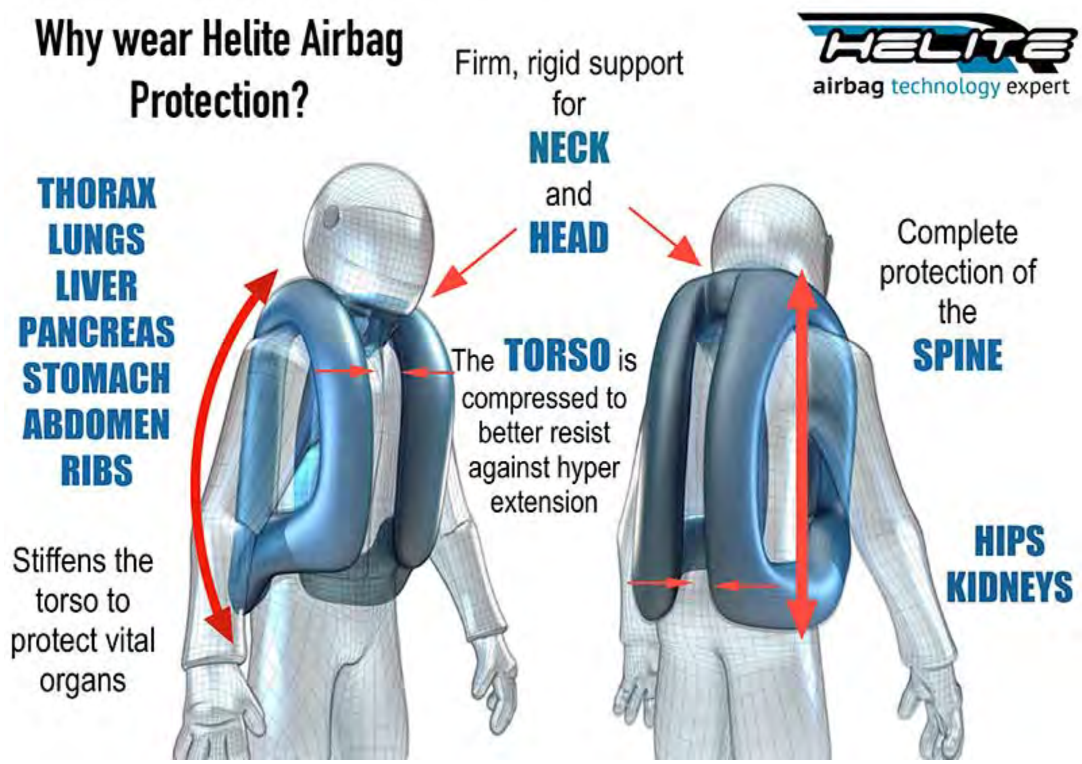


Figure 3 – 6 - 9 **An overview of the Helite Airbag Protection system.**

https://helite.com/

The importance of the harness is to replace the traditional helmet, which many users found uncomfortable. On average only 18% of riders end up wearing helmets. Citing discomfort and cost as reasons not to wear them (Taylor, 2019). By designing the harness to be adjustable, riders can safely operate their vehicles without the fear of feeling hindered. Since the harness is designed to be triggered in the event of an accident, the user can be confident in the ability to stay safe in the event of a dangerous, high-speed accident. The user's expressed interest in the idea of using the harness as the straps for the storage pouch on the scooter. Further exploration into this concept will be carried out to find an ergonomically sound way of easily detaching and accessing the bag.

Figure 3 – 6 - 10 **Promotional shot for Microsoft HoloLens V2.**
https://microsoft.com/

The heads-up display idea was inspired by the need to access and receive important information during the commute. In a more connected world, the need to be constantly "available" is more important than ever. Rather than completely removing this information (which still leads to instances of distracted driving), this data can be shown and easily interacted with or dismissed with little input from the user. Projecting the rear image to the rider, the need for the driver to become distracted with what's behind them. A common hindrance to micro-mobility riders is unexpected obstacles and changes in elevation can lead to accidents. These collisions prove especially dangerous during high-speed commuting and traffic. By projecting information onto the rider's glasses, these hazards can be quickly highlighted, allowing the user to react accordingly. Similar technology can be found in self-driving vehicle projects and is constantly improved through over the air software updates. A connected, ever-improving ecosystem is vital to not only a safer commute but encouraging traditional vehicle owners to consider taking a more environmentally and socially conscious effort for inner-city commuting.

3.3.6 Limitations and Conclusion

After identifying the specific limitations of the vehicles, several conclusions were built:

- The vehicle would need to be portable enough to bring along during commutes.
    - The vehicle will need to be "collapsible"
    - The vehicle would need to be able to "drag" behind user
    - The "storage" unit will need to be able to be easily removed
    - Weight, weight distribution considerations
- The Remote spacing and controls are to be stationary.
    - The comfortable distance was measured to be 12" apart.
    - The vehicle and its movements and signaling mechanisms are to be operated by remote oversteering.
    - Configurable controls and presented content.
- HUD must be able to be easily used.
    - Accessible at any time
    - Configurable and lightweight
    - Alerts user's subtly.
- Safety harness must be comfortable to wear.
    - Lightweight and unobtrusive

- Alerts other drivers to the presence
- Airbag control to prevent major limb and organ damage

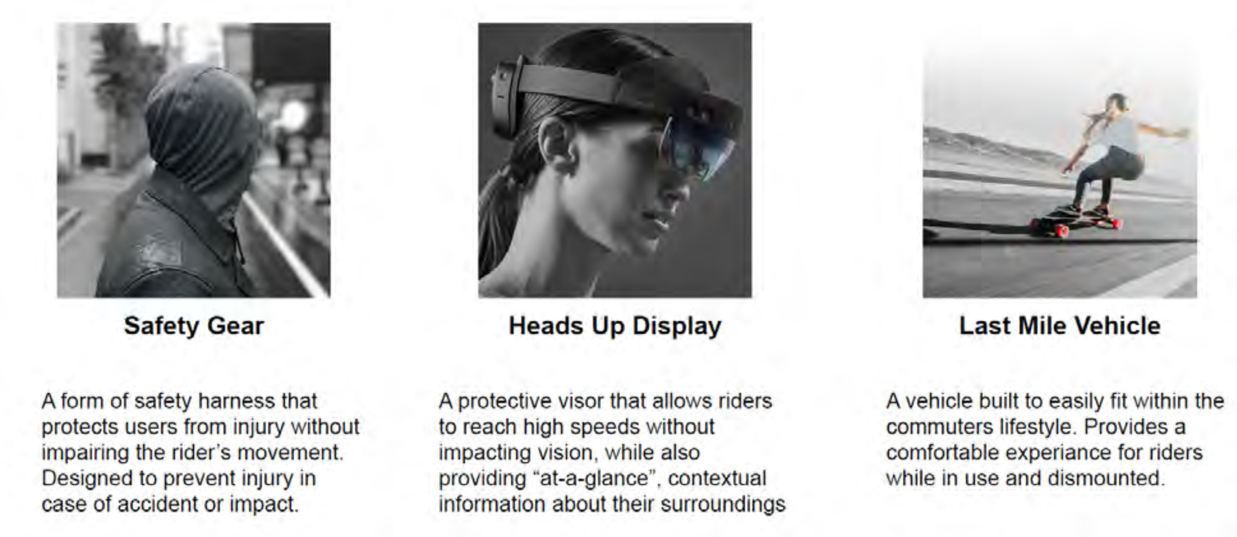


Figure 3 – 7 Overview of the proposed system.

3.4 Aesthetics

Vehicles

The Last Mile Vehicle, much like the automotive industry, presents users with a diverse variety of form factors to suit different user needs. Everything from the method of operation, to the number of wheels, varies based on the rider's preference. While the overall form changes between devices, they all maintain a similar, minimalistic aesthetic. This is primarily done to make vehicles accessible to a wide audience, often offering different color customizations and graphic elements to them. The design aesthetic and materials match the interaction that users will have with the vehicle. Although once considered "counter-culture", many companies have started streamlining and gentrifying the overall aesthetic of their vehicles; primarily publicly shared vehicles. This clean aesthetic can be viewed as new, futuristic, and enticing to try for the novelty of it.

Figure 3-8-1 – Woman riding Lime-S Scooter. Photo by Lee Devito for The Metro Times.

https://www.metrotimes.com/the-scene/archives/2018/08/28/detroit-now-has-two-electric-scooter-services

By maintaining a clean, minimalistic aesthetic for the vehicle, it will not seem so alien and foreign to pedestrians and other motorists.

Heads Up Display

While the concept of portable phones becomes more commonplace in society, the advent of wearable Augmented Reality hardware still faces some scrutiny. Primarily due to privacy concerns and initial shock. This discomfort of smart glasses can be seen in the failure of Google’s ‘Project Glass’ efforts, switching from a consumer prototype to an enterprise solution after users failed to generate interest in the face-mounted camera. Recent efforts from companies like North with their focal line, to Snap Inc. and their Snapchat Spectacles, show a trend of interest with smart glasses that appear as normal eyewear.

Figure 3-8-2 – Woman poses with Google Glass in the press material. Press release photo by Google Inc.

https://www.cnn.com/2014/04/14/tech/mobile/google-glass-attack/index.html

By mimicking a familiar form factor, the idea of AR glasses being worn, especially to protect the rider's eyes from dust and debris, without providing any form of confusion or worry of privacy loss to those around the rider.

Safety Equipment

As mentioned previously in the report, the current landscape has not caught up with the speed and capability of modern Last Mile Vehicles. Although improvements have been made in the materials, comfort, and the aesthetic of safety devices, they still are bulky and often intrusive to the user. In the interviews that were conducted with LMV riders, many of them expressed a lack of interest in wearing safety equipment due to the discomfort experienced by them. There has been an increase in interest in the adoption of more protective gear. As recognized in the previous chapter, the recent interest in airbag jackets has led to an interest in protective fashion as an aesthetic

3.5 Sustainability – Safety, Health & Environment

Already presented as an environmentally friendly substitute to standard vehicles, the sustainability of the LMV experience is ever-present in the discussion of these alternate modes of transportation. The importance of rider safety and health is paramount to the successful development and deployment of a potential "Last Mile Vehicle" system.

Safety

As the thesis topic revolves around the improvement of LMV operation, safety is the number one priority to the design solution. Risks that are encountered during regular commuting will inherently be presented to the rider. The build of the vehicle will need to fit the current standards required for safe navigation in urban areas. Information such as speed, battery percentage, navigation and hazard indication will need to be presented to the user in a non-invasive way to continue safe operation. This data can be presented subtly and innovatively to the rider. The movement made by the rider must also be telegraphed to surrounding users to increase visibility and ease the tension between travelers. Materials that are designed to be weatherproof will need to be chosen. Fabrics will need to be easy to clean to provide a better user experience.

Health

In the context of this thesis, the 'health' of the user refers to the aspects of commuting that impact the user's wellbeing in the long run. This includes factors that are often overlooked, like the posture of the user, necessary areas needed to be protected during a collision, and factors that impact the users' mood and comfort while operating these vehicles. The benchmarking of existing products shows that there is a lack of a cohesive system that makes the riding experience safer for the operator. The smaller build of the vehicles leads to users dismounting and carrying them on their person. The act of staying mobile and active lends to the healthy nature of LMV.

Environment

Since micro-mobility is viewed as an environmentally sustainable and friendly way to commute, the importance of minimizing the environmental impact that the rider will have on the urban landscape. The benefit of working with a smaller footprint means that there are fewer complex components that require potentially environmentally damaging parts. By designing this solution as an all-in-one system of products, the need to build and assemble the goods requires little in the sense of storage post-construction, to larger, less environmentally conscious methods of transportation to retail centers or customers' homes.

Product Repairability

Although current LMV is designed to be easily repaired by the user, safety equipment is much more difficult to responsibly manage. Many of the current impact solutions require single-use materials that are damaged beyond repair once their need is carried through. This creates a large amount of waste generated and requires the user to spend more to replace essential products. By maintaining the modular design that current LMV manufacturers support, identifying and remedying problems becomes easier to do for users, and produces less single-use waste should the OEM support the reusability of older and damaged components.

3.6 Commercial Viability

The following section will hypothesize the cost, materials, and manufacturing of the proposed solution. For contextual insight, at the point of writing this report, we are right at the beginning of a manufacturing paradigm shift with the impact of the COVID-19 pandemic. Impacting an industry in unprecedented ways. As this is strictly a hypothesized experiment, the time frame in which this content is being presented is within the scope of the year 2019. Any speculation as to the impact of COVID-19 on the manufacturing chain, cost of components, and viability of this product will not be used within this section.

3.6.1 Materials & Manufacturing Selection

The materials used in each component of the system requires specific characteristics to improve the overall experience. Factors such as weight, texture, and durability all play into the equation.

HUD

Since this component is more immediate with the rider, materials, and technology embedded within the wearable must be chosen carefully. The idea behind manufacturing a sophisticated pair of AR goggles that also doubles as a protective visor carries with it a concern with keeping the embedded technology safe from the elements. By relying on a remote processor built into the vehicle, the HUD dramatically decreases in weight, battery usage, and cooling requirements. This also frees up the chassis to incorporate the necessary cameras, lenses, sensors and laser projectors needed to run the equipment.

Figure 3-9-1 – Teardown of the Microsoft Hololens V1. Photo by The Verge

https://www.theverge.com/2016/4/6/11376442/microsoft-hololens-holograms-parts-teardown-photos-hands-on

As seen in figure 3-9-1, there are a lot of fine pieces that are required with a standalone AR headset. Although this also impacts the repairability of the HUD, design considerations such as modular components, removable battery, and embracing hobbyists and DIY enthusiasts encourage not only a platform that users can create experiences and improve but also leads to a system that will be able to be updated and supported well after the product is released.

Safety Equipment

The immediacy of the safety equipment is felt the most. The hindrance and discomfort of a helmet, the large, bulky feel of leather or jean jacket. The inability to have a free range of motion while you ride. By manufacturing a comfortable, unobtrusive safety harness that frees the wearer up to be able to move comfortably. However, there should also be considerations for the deployable safety bags stored within; from aesthetics to repairability. Rather than scrapping the entire product after it served its purpose, it would be more beneficial to simply replace components of it. This allows for additional product support through the purchase of "replacement bags" and using biodegradable material for the protective cushioning encourages a more environmentally friendly solution.

Figure 3-9-2 – Nike iSPA Inflatable Jacket concept blends function with unapologetic form. Photo by Nike

https://news.nike.com/apparel/nike-ispa-inflate-jacket

Vehicle

As the main product in the ensemble, material choice is essential to the design of the main chassis. The use of durable, weather-resistant material that can also be customized as per the user's preferences requires a material that has been proven as useful in the automotive industry, borrowing its construction from the autonomous factories and assembly plants. Companies like Tesla have shown that a large yield of vehicles can be assembled and deployed without the need for human interaction as seen in Figure 3-9-3.

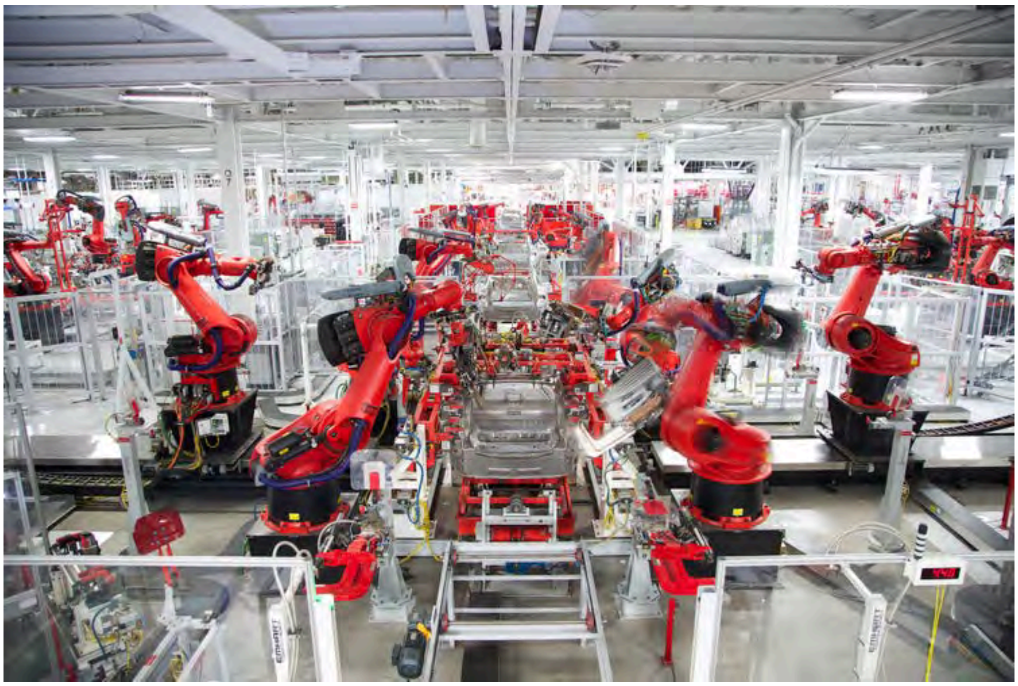


Figure 3-9-3 – Tesla manufacturing plant in California. Photo by Tesla Inc.

https://www.businessinsider.com/tesla-plan-to-build-factory-in-germany-makes-no-sense-2019-11

3.6.2 Cost

HUD

Similar in functionality to Microsoft's HoloLens AR headset, the cost to manufacture, assuming it is to consist of existing technology, parts, and software, can be close to \$600 - \$900 (Slater, 2020). An MSRP of \$1100 would be a reasonable cost for the equipment.

Safety Equipment

Similar product's current retail between $400 - $900 for single use Airbag Vests. If this technology is minimized to a point where 5 airbags were to be deployed on various parts of the body (Neck + Head, Left Arm, Left Leg, Right Arm, Right Leg, Back) based on the severity of the crash, there is a chance that individual "pods" could be sold independently to the vest. This way, any loss from selling the hardware of the vest is recuperated in the sale of the replacement airbag pods.

Vehicles

Already having the benefit of not needing to be licensed, the vehicle itself can be sold without the interference of government bodies. This already reduces the cost for the consumer. Although each vehicle is identical in components due to the adjustable nature of the vehicle, standard parts can be manufactured and assembled, changing only the material used. This can open the market to different tiers of vehicles, varying in colour and materials used.

3.7 Design Brief

The purpose of this design thesis is to develop a system to improve the overall safety of Last Mile Vehicle riders through a series of product solutions that form a functional system. Based on information analyzed in the chapter, the objectives which will be addressed in the final design solution are as follows:

- Incorporate passive and active security features for the rider
- Connect a series of independent products into a cohesive system
- Quell user concern when it comes to unknown ride metrics through at-a-glance information

- Minimize footprint when in transport or use
- Sustainable materials designed to be durable and easily maintained or repaired
- Ensure rider can fit products into their current workflow and commute
- Easy to learn and master user interface for vehicle and products
- Aesthetically cohesive design language between products
- Stable and secure feel while riding and commuting with system
- Unobtrusive design when it comes to wearable safety equipment

4 Design Development

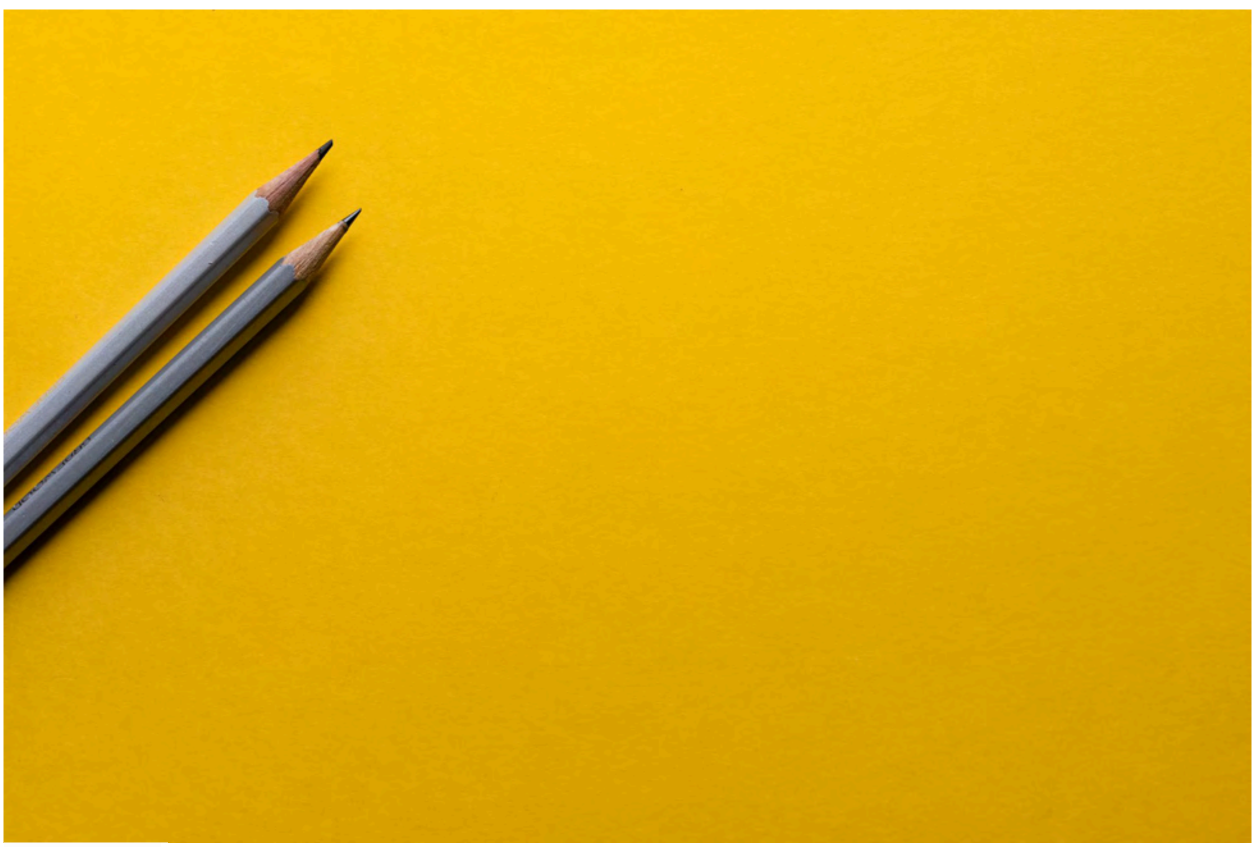


Figure 4-1-2 – Two gray pencils on a yellow table. Photo by Joanna Kosinska on Unsplash.

https://unsplash.com/photos/1_CMoFsPfso

The following chapter demonstrates the design process of the proposed Last Mile Vehicle concept, the Heads-Up Display, and the Protective Vest. Although all product shapes are explored, the focus of the physical design study will be on the vehicle itself.

4.1 Ideation

Micro Vehicle - https://www.pinterest.ca/pin/360921357632720471/

Voice Command Robot - https://www.pinterest.ca/pin/357965870381264907/

Segway Minipro - https://www.pinterest.ca/pin/243968504801863330/

Genesis Mint Concept - https://www.pinterest.ca/pin/621215342331084406/

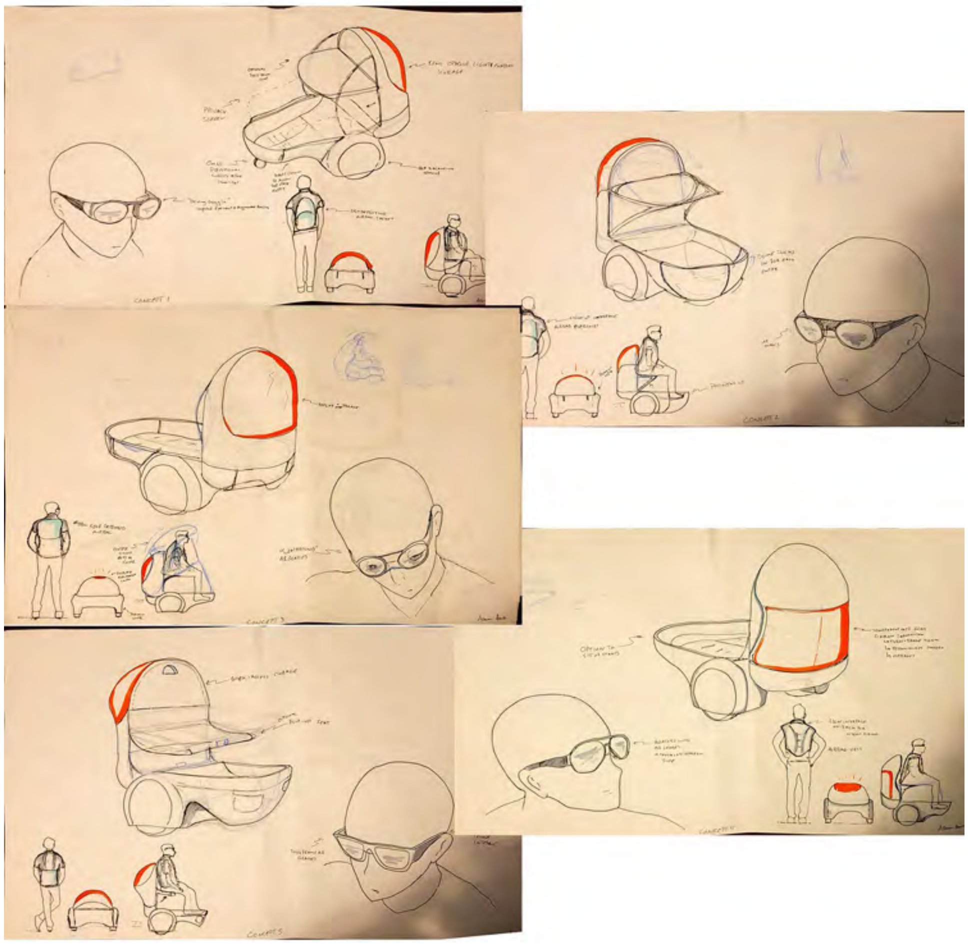
Car Illustrations by Christopher Hebert - https://www.pinterest.ca/pin/354095589441402259/

Black Emptiness by Jan Kalab - https://www.pinterest.ca/pin/360921357632720471/

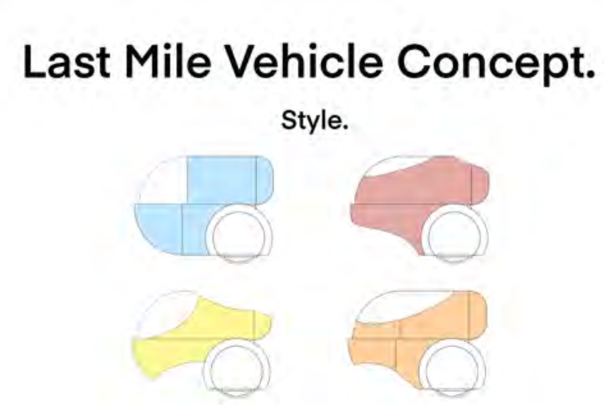
Early inspiration for the overall design language came from the playful, bubbly aesthetic found in many city cars. The form and functionality of the Segway evoke both the familiar and the futuristic. For aesthetic inspiration, symmetrical, "gliding" animals like the Stingray became an organic shape with a fluid motion that later went on to inspire some of the 'functional' aspects of the vehicle concept. The friendly yet robotic charm of these 'smaller' products helps those otherwise afraid of newer technology to become more sympathetic to the device.

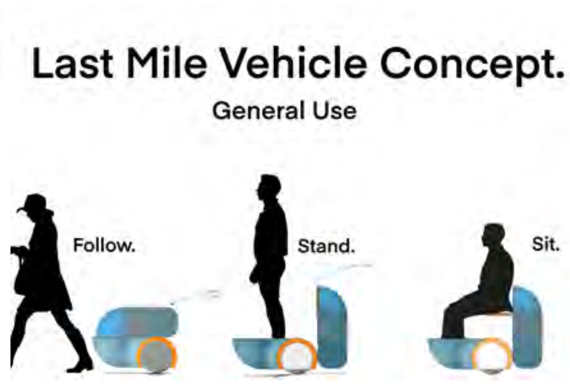
Initial concepts for the headset, vehicle, and vest were drawn. Once a form factor was established, it was time to further explore the concept.

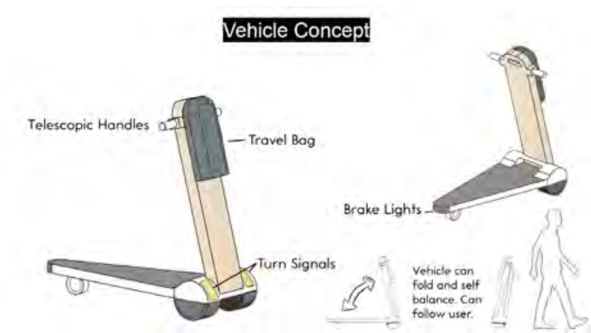
4.2 Preliminary Concept Exploration



Initial exploration was done on a small carrier pod that would open up to either seat or holds the user while they stand. Glasses styles were explored to gain a “feel” for each vehicle’s aesthetic. The protective vest was beginning to take form with some light styling exploration.



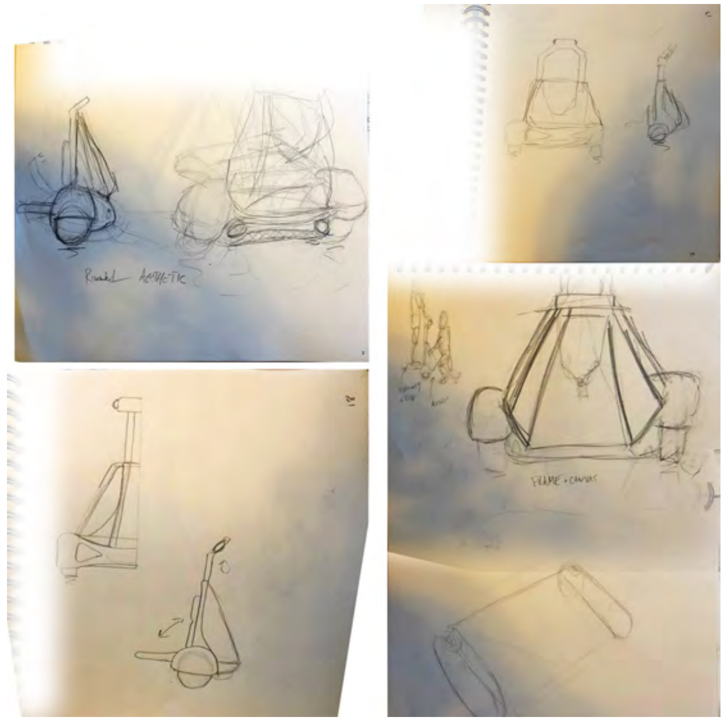




Due to the variety of vehicle types, it was important to further explore the overall shape, sizing, and feel of the LMV. By exploring refined shapes, and overall style could begin to be developed. Features such as the automatic following, storage units, ambient lighting, balancing on two wheels, and standing position began to form.

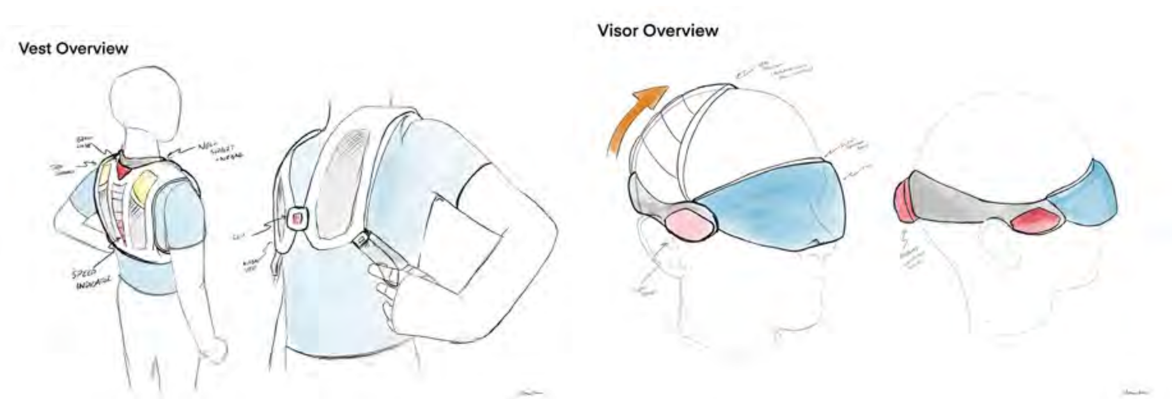
4.3 Concept Refinement

Different lenses and vest concepts were drawn, different styles were explored. The use of haptics, lighting, and airbag positions began to incorporate themselves into the design.

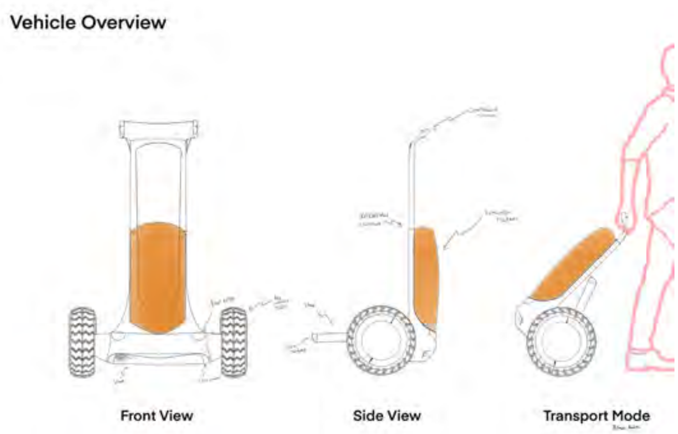


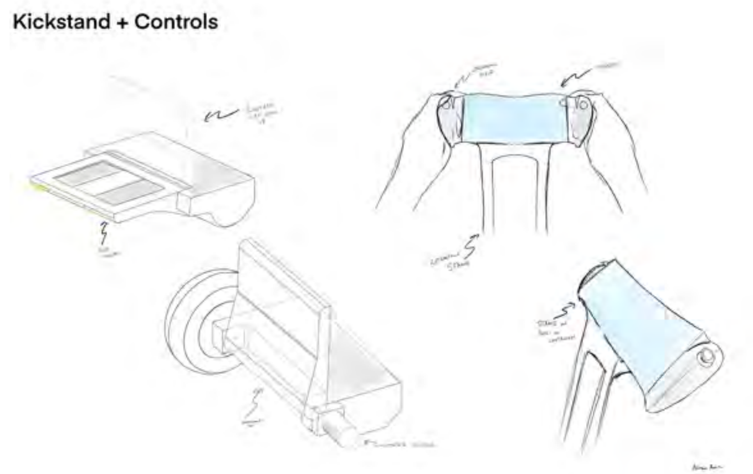
At this point in the design, the final form began to take shape. Many aspects from this design would later be found in the later design stages; while designing the 1:1 scale mockup, and the sketch model.

4.4 Detail Resolution



The final forms for the vest and visor began to take final form. Some features were explored and ultimately decided against for the final design.



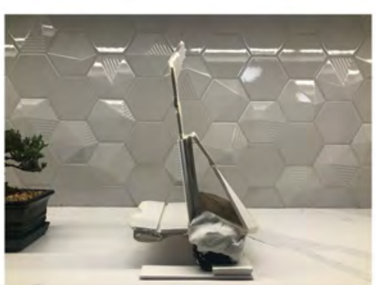


The final vehicle form and function were designed. The extending handle which doubles as a carrier grip was established. The folding out stand for the rider was incorporated into the product. The ergonomics of the grips were established.

4.5 Sketch Model

Before a sketch model could be built, the ergonomic report provided dimensions for each component.

The scale model was assembled using foam core, magnets, 3D printed tires, dowels, modeling clay to assist with the organic form factor, and LED lights for effect.



4.6 Final Model

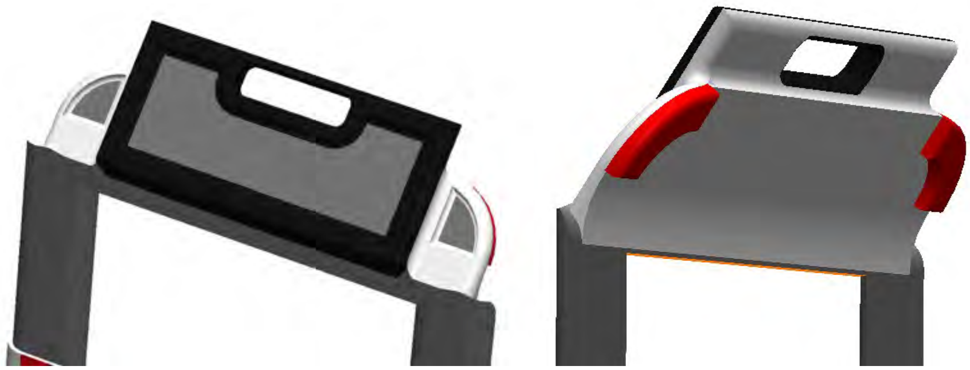
The sketch model was built to realize the specific scale and components needed to be built to assemble the model. The full scale as documented in Chapter 3.3 Figure 3 – 6 – 2 was scaled down to 1:4 for the final model. This scale was chosen due to the ability to add details without creating a massive model. An adjustable grip, removable storage, dynamic stand, and LED ambient lighting was added for visual interest.

4.7 CAD Model

Once a final form factor was established, and a 1:4 scale model was prototyped, the final CAD work could begin.

Expandable Rail

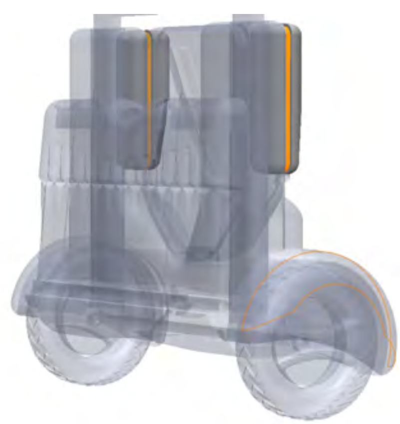
Designed to allow more users to use the vehicle more comfortably, the expandable rail consists of the main display + grip as well as a locking mechanism that holds the controls at set heights.



The control system for the vehicle includes ergonomic grips displaying two haptic touchpads that are used to control various functions of the vehicle; from turning to speed. When used in conjunction with the HUD, the display information is projected in front of the viewer, reducing their need to engage with the vehicle's display. Information such as speed, location, and fielded calls + messages are shown to the rider contextually to avoid any distractions while driving.

Bags


the removable storage bag that matches the overall aesthetics of the vehicle can be worn on the back of the user's safety harness. This allows the vehicle to track the user's position and follow them when they dismount the vehicle.

Optional side bags are available to mount to the vehicle to accommodate user requirements. Accent lighting can be found displayed around each bag variant, providing more visibility to riders under lower visibility conditions.

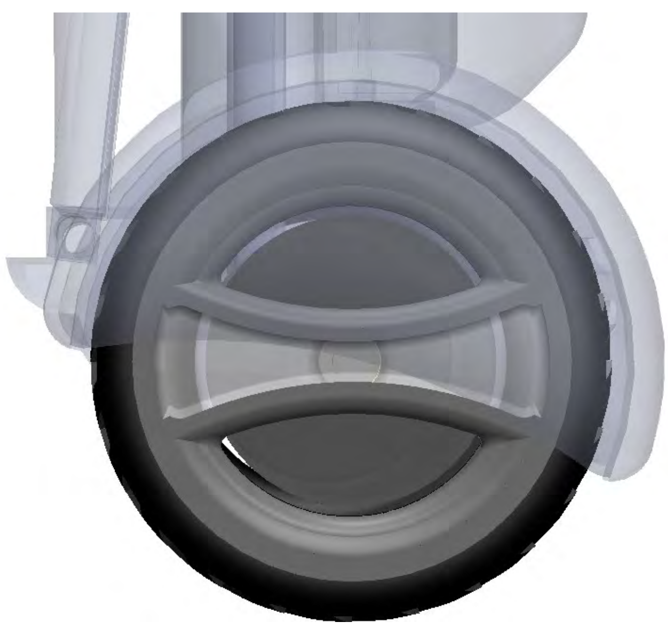
Vehicle Body

The main body of the vehicle houses the required sensors, batteries, motors, and computational power needed to operate the vehicle. Lowering the center of gravity by keeping the densest elements of the vehicle within the center mass of the vehicle, users feel a sense of stability and presence while riding.

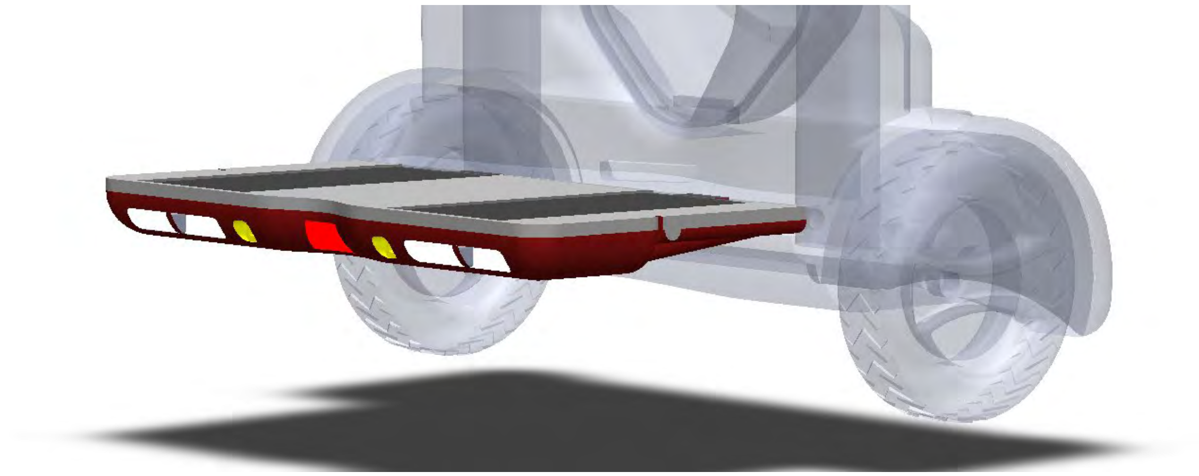
Adorning the chassis are signal lights, proximity sensors, 5G, and radar arrays to provide semi-autonomous operation. The bold colour choices of the body are customizable for each owner.

Wheels

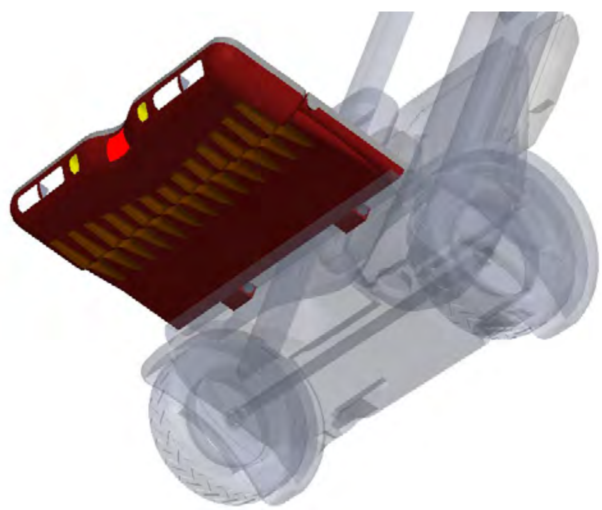
The rims were designed to provide an interesting visual as the vehicle is in motion; reflecting the surrounding ambient lights to notify other motorists of their presence. All-Season, wider tires were essential to providing further security and comfort should the terrain be impacted by the elements.



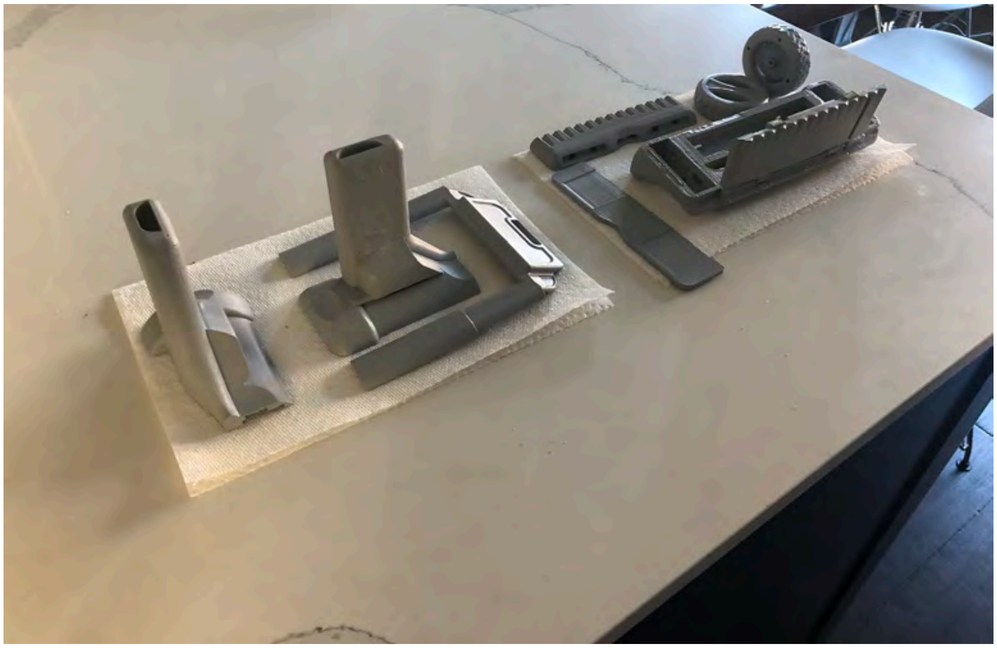
Stand



Built to support the weight of the user, and to give the appearance of 'levitation', the rear stand is revealed to the rider when they are ready to embark on their journey. When in follow mode or charging, the rear stand folds into the back of the vehicle.



4.8 Hard Model Fabrication

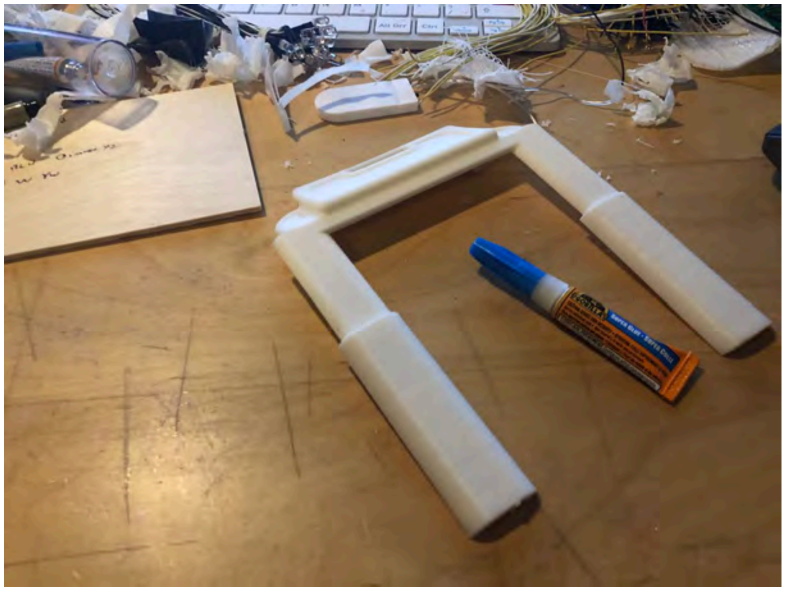


The construction of the physical model began with minor adjustments to the CAD file to accommodate:

- Points of connection between moving parts.
- Size of the print to accommodate the print bed of the 3D printer.
- Shelled components to house wiring for LEDs.
- Cut areas to accommodate magnets.

These parts were printed using a Monoprice Select Plus and PLA filament.

Expandable Rail



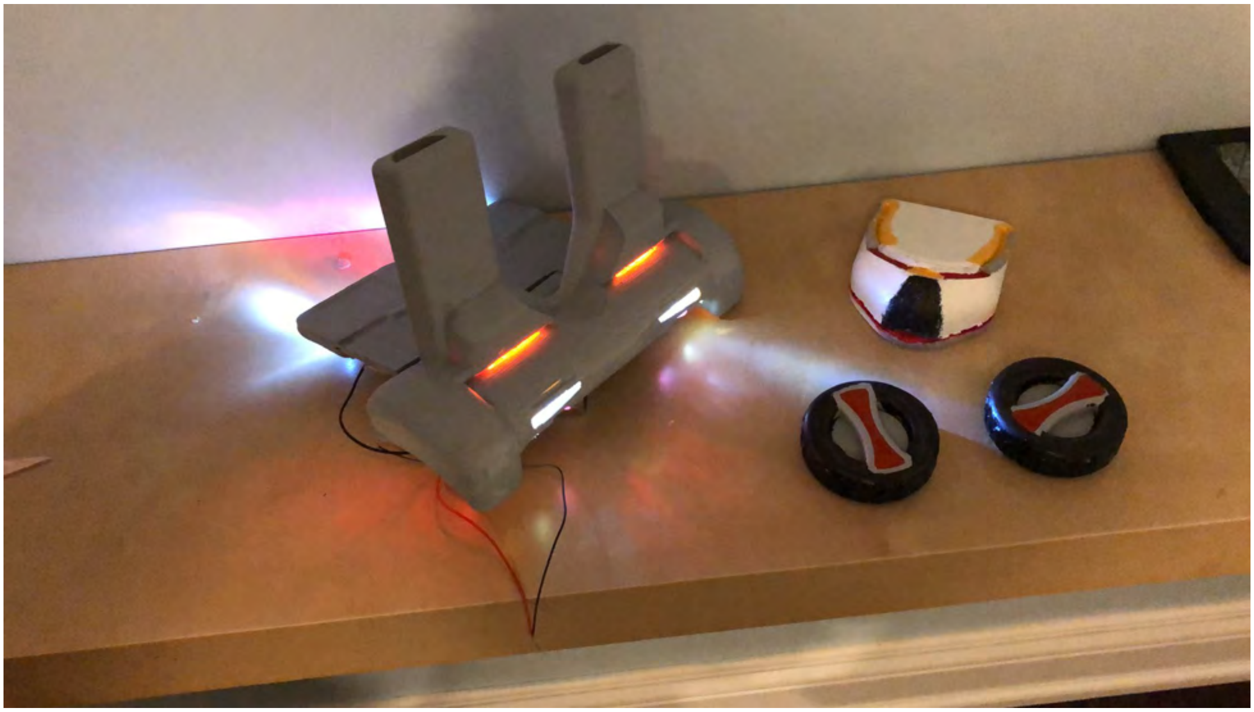
This part was printed in three separate pieces; the control screen, and the two expandable bars. Grooves were placed in the two smaller pieces to guide the main piece into them. Superglue was used to create a strong bond between the pieces.

Vehicle Body

The vehicle body was printed in 4 parts. The bottom half of the vehicle is held together using a dowel and epoxy. As seen above there was space built to hold the wiring necessary to give the model lights.

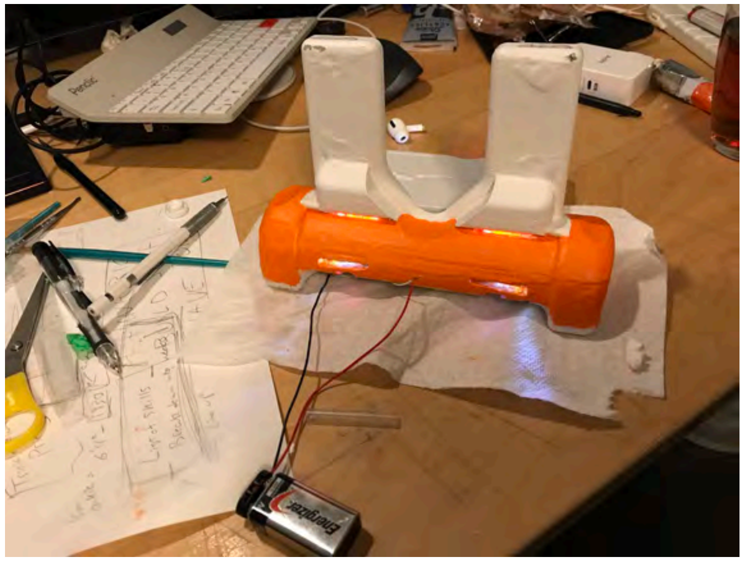
The rear stand was assembled and attached with a dowel, allowing for movement.

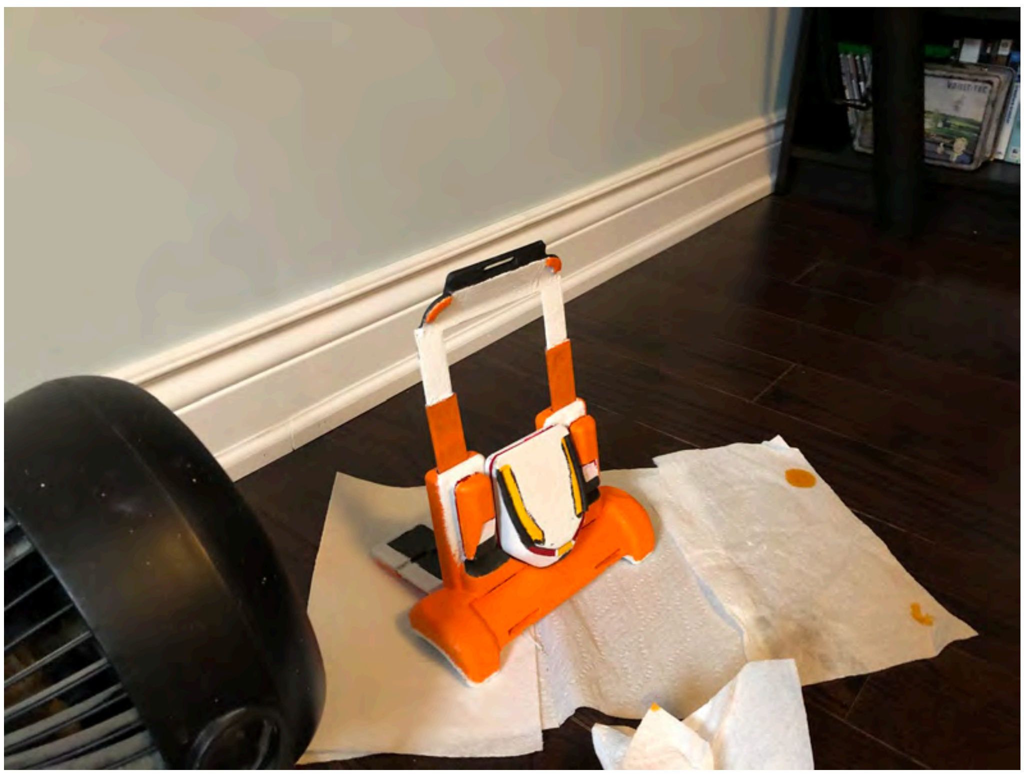
After the parts were primed, the top and bottom were outfitted with lights. Once sanded, the top and the bottom were joined using epoxy. Gaps were filled using a multi-purpose filler, then sanded once dried.



A prime coat of white was applied to the model once the primer set. This was applied with a pass of spray paint and later touched up using model paint.

The orange accenting was applied to the model. Enamel was used for the rims, main screen, and side controls to give them a glossy look and feel.





5 Final Design

This chapter is a culmination of the data from previous sections demonstrating how the design solution fulfills the requirements of the thesis. Final CAD work, ergonomic considerations, and model photography will be featured heavily here.

5.1 Summary

Description

Helios, named after the Greek god of the Sun, was believed to ride a golden chariot across the skies each day. The vehicle designed, while greatly resembling a chariot, involved the use of ambient lighting and signals to provide the rider with a more comfortable experience. 'heliOs' is a modern take on urban exploration, empowering users to easily traverse urban sprawl in a more convenient, environmentally friendly way.

Explanation

Since Last Mile Vehicles are still seen as a niche product, 'heliOs' was designed to aid in the adoption of this kind of technology, which has been shown to dramatically reduce traffic congestion and sound pollution, as well as acting as a more environmentally and economically conscious decision over owning a car. Through the use of signal lights, sensors, adjustable controls, and other safety considerations, the LMV experience is heightened; nullifying many concerns faced by users hesitant to switch

Benefit Statement

'heliOs' is a Micro-Mobility solution that provides users with a safe, less intimidating experience augmented through semi-autonomous features and equipment to help ease new riders into the transition to smaller vehicles.

5.2 Design Criteria Met

This section discusses various elements of the Last Mile Vehicle design and how each component is implemented.

5.2.1 Ergonomics

Controller

The controller was designed to be comfortable to operate regardless of height; as it is attached to a rail system that can raise or lower depending on the users' needs. The spacing of the two grips was designed based on a common width that was determined not to cause strain from extended use. The contour of the grips themselves and the haptic inputs was chosen to keep the wrist in a natural position without twisting them. Haptic movement controls and an AR/ touch interface for the primary screen are technologies and inputs that the target users are familiar with.

Follow + Carry Mode

heliOs was designed to be compact enough to easily transport on public transit, while also large and present enough to be safely ridden. The height the unit compresses to, as well as the size of the grip embedded into the controller, was chosen to accommodate the rider should they choose to cart their device.

Safety Equipment + HUD

Considerations were taken to remove the burden of safety equipment for the rider; replacing traditional helmets and kneepads with a vest with built-in sensors that release airbags depending on the contextual need. The HUD was built to be comfortably worn by all users and project information relevant to the rider.

5.2.2 Materials, Processes & Technologies

The manufacturing processes, as discussed in Chapter 3.6.1, would be similar to major automotive manufacturers like Tesla Inc.; fully autonomous manufacturing. The materials used would consist of Aluminium, with a mix of high strength steel. An assembly inspired by the mixed chassis of the Model 3 (Loveday, 2017).

OLED panels and haptic input devices have lowered in price since they were first introduced. This allows for these technologies to be implemented at a significantly lower cost then what was available before. The horizontal touch display of the controller and the haptic control grips on the sides are then able to be effectively installed.

The motors necessary to balance the rider and the vehicle, as well as the high powered battery are the two heaviest components within the vehicle. By assembling them into a single unit, the repairability of the unit increases. Lowering cost that is often associated with hard to repair components.

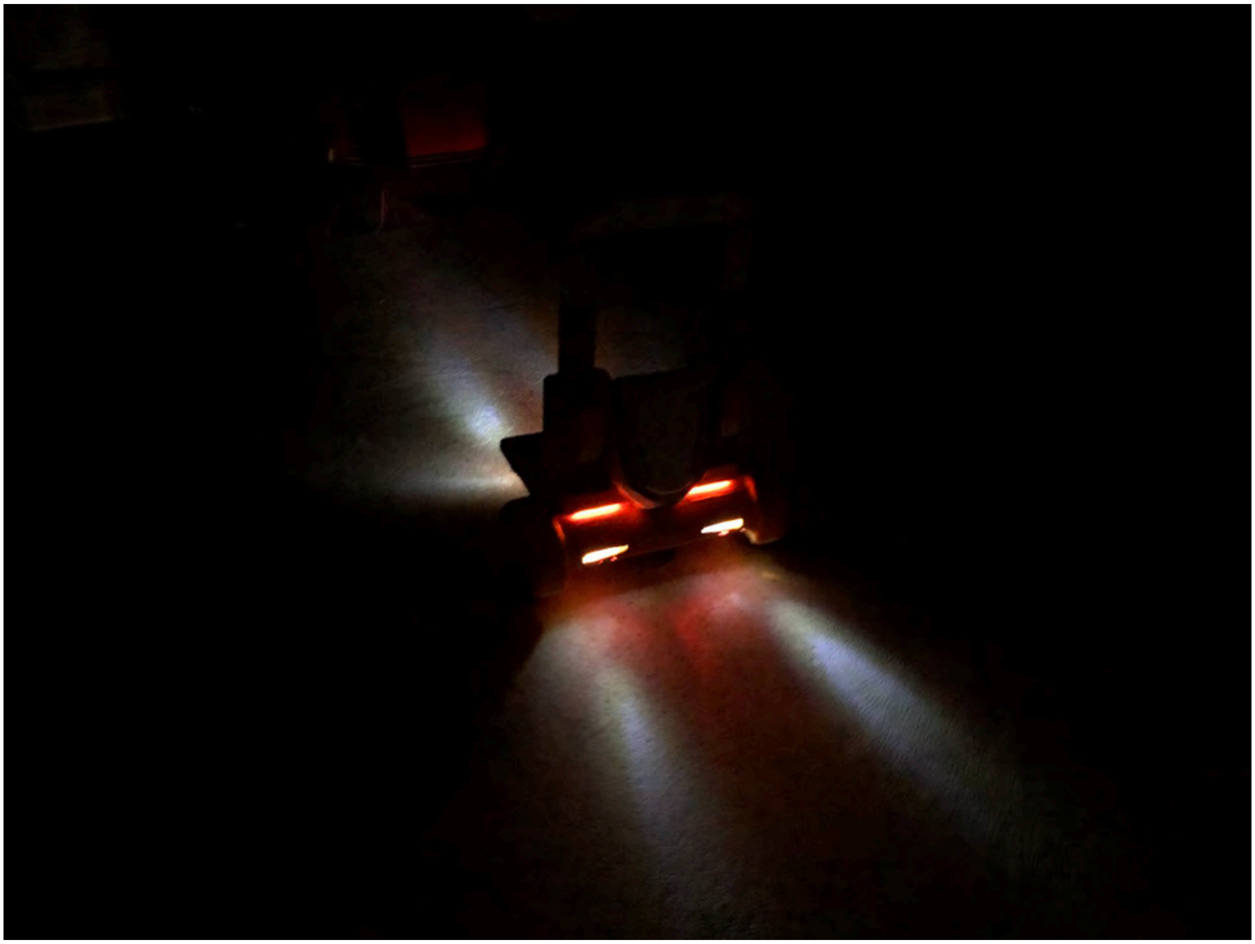
5.2.3 Manufacturing Cost Report

Based on the components and processes discussed above, an estimated cost to manufacture the vehicle is calculated.

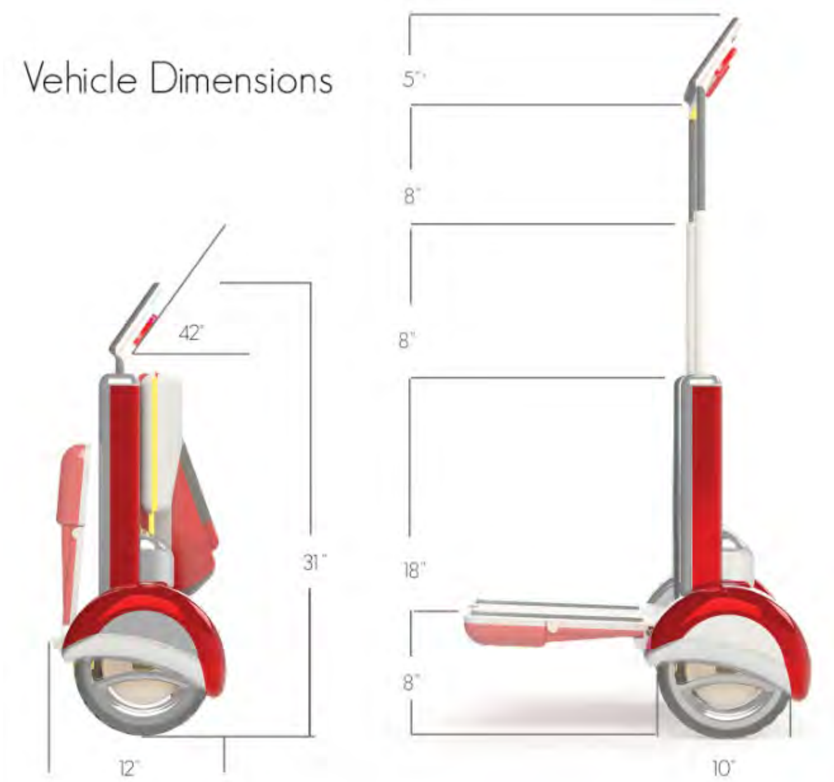
Item	**Quantity**	**Estimated Cost**
OLED Display	1	$95
Control Grips	2	$50
Motors	4	$95
Wheels	2	$350
Top Chasis	1	$500
Stand Chasis	1	$300
Bottom Chasis	1	$400
Main Bag	1	$60
Side Bag	2	$40
Battery	1	$300
Lights	28	$3
Sensors	5	$20
Total		**$3,099**

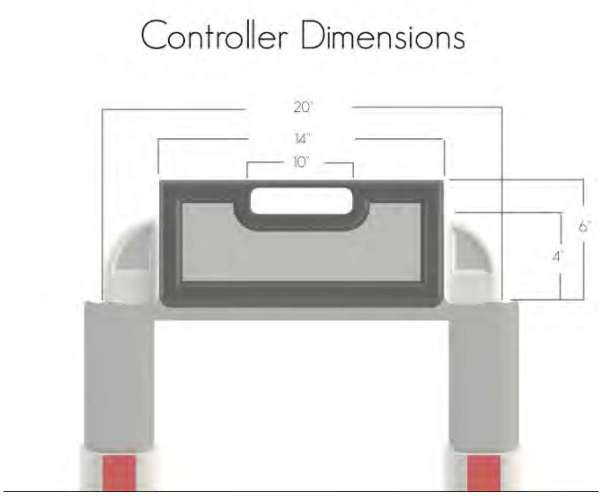
5.3 Final CAD Renderings

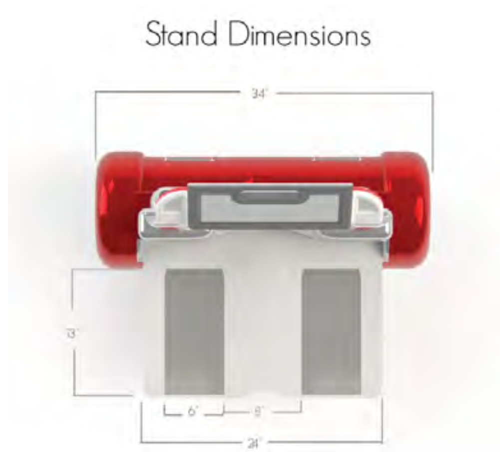
5.4 Hard Model Photographs



5.5 Technical Drawings







5.6 Sustainability Summary

Last Mile Vehicles can become a sustainable way to navigate an urban environment; in both an environmental and growth means. Those who use these kinds of mobility devices contribute to a less busy street, less sound pollution, and rely less on contributing to harmful emissions found in traditional means of travel. The materials chosen for the 'heliOs' were selected due to their durability, as well as their proven ability to operate in harsh conditions. Finally, the onboard sensors and software are designed to be futureproofed, adopting whatever protocols and necessary changes that may come.

6 Conclusion

heliOs is the next step in urban transportation. By combining the best aspects behind Last Mile Vehicle commuting and portable storage solutions, heliOs can adapt to a rider's needs throughout the day. Whether it’s cruising through traffic during rush hour, or taking the subway. Built-in sensors and signal lights allow riders to safely merge in with existing modes of transportation while providing a sense of unparalleled control and autonomous navigation. A safety harness allows for extensive protection during an accident or collision; deploying airbags depending on the area of impact and severity of the crash. A Heads-Up Display system projects the upcoming topology for the user to see as well as indicating their speed, navigation information, and other contextual information. By removing more conventional vehicles off the road, heliOs are designed to provide new and experienced riders a level of comfort, security, and confidence which is not found in contemporary Micro-Mobility vehicles.

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Man and Woman standing near the railing of the river. Photo by Timur Romanov on Unsplash *https://unsplash.com/photos/osNaWvJ1D1E*

White road bike leaning on the teal wooden wall during the daytime. Photo by Carl Nenzen Loven on Unsplash *https://unsplash.com/photos/igKjieyjcko*

Man riding a skateboard on road during the daytime. Photo by Yomex Owo on Unsplash *https://unsplash.com/photos/TuB8Za2lZ-g*

Group of people riding Segways. Photo by Johny Vino on Unsplash

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Man driving vehicle. Photo by Victor Xok on Unsplash

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People crossing a street in Vienna. Photo by Jacek Dylag on Unsplash *https://unsplash.com/photos/PMxT0XtQ--A*

Bird electric scooter riders in Santa Monica, California. Photo by Dan Tuffs of The Guardian https://www.theguardian.com/cities/2018/apr/25/electric-scooters-urban-transport-bird-santa-monica-uk

Self-balancing unicycles at 'Paris sans Voiture' (Paris without cars), September 2015. Photo uncredited on Wikipedia https://en.wikipedia.org/wiki/Electric_unicycle

Electric Bicycles lined up ready to be rented. Photo uncredited on Medium https://medium.com/cityoftomorrow/lets-go-for-a-spin-ford-buys-scooter-company-to-provide-customers-a-first-last-mile-solution-bbeae278d373

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Save yourself a few steps with electric transportation. Photo by Josh Miller for CNET. https://www.cnet.com/news/electric-scooters-are-amazing-last-mile-transportation/

Woman riding Segway in an urban environment. Photo by Timur Romanov on Unsplash. https://unsplash.com/photos/f1Hsmb4f5Z0

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Woman riding Lime-S Scooter. Photo by Lee Devito for The Metro Times. https://www.metrotimes.com/the-scene/archives/2018/08/28/detroit-now-has-two-electric-scooter-services

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Nike iSPA Inflatable Jacket concept blends function with unapologetic form. Photo by Nike https://news.nike.com/apparel/nike-ispa-inflate-jacket

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Two gray pencils on a yellow table. Photo by Joanna Kosinska on Unsplash. https://unsplash.com/photos/1_CMoFsPfso

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8 Appendix

Appendix I - Discovery

Information Search – Preliminary Report

The objective of this report is to explore research methods and information searches for a prospective thesis topic using a variety of academic sources. The specific area of focus will be the human needs that are being met by the form and function of a design. By using quick research methods, we are familiarizing ourselves with the steps needed to complete chapters 1 and 2 of our final thesis reports. Two articles will be researched and reported on during this report. The first article will be a scholarly paper taken from a peer-reviewed journal, the second article will be an internet review of the design.

Search Topic

The area of focus for this preliminary report is consumer grade, electric LMV (Last Mile Vehicles). The use cases of a variety of different high speed, single passenger vehicles will be the topic of search. This research is necessary in order to answer the proposed problem; ‘How can we improve safety for Last Mile Vehicle operation?’. In order to further alleviate traffic congestion within major urban areas, commuters often purchase or rent LMV which, as the name suggests, helps cover the “last mile” of travel. This mode of transportation is often used in tandem with public transit or a primary vehicle. Safety concerns arise as these vehicles increase in both number and speed.

Current methods are traditional helmets which help avoid any major head trauma, however the risk of bodily damage is still a major cause for concern.

Key Article 1

Method

Search Engine: Google Scholar

Key Words Used in Search: "Review Electric Longboard"

Findings

Citation: Cuffe, P. (2018, April). Flexible mobility in the smart city: the role of small personal electric vehicles. In *DIT–eseia Conference on Smart Energy Systems in Cities and Regions, Dublin, Ireland, 10-12 April 2018*. Springer.

Key Content:

Abstract

A new class of personal vehicles, sometimes called ridables, has recently attained a level of technical maturity. These electric vehicle are light, portable and suitable for transporting an individual person in an urban environment. As batteries become increasingly affordable and energy dense, the range and capabilities of these vehicles are correspondingly enhanced. Notably, many ridables are suitable for intermodal commuting, as they are typically small enough to be brought along on a bus, train or tram. As such, this new class of vehicles seems to offer particular value for urban commuters, though this emerging use case has not been widely discussed in the extant literature. The present work seeks to provide a brief survey of the capabilities of the relevant vehicles, and to discuss some initial loose estimates for the portion of urban

commuters for which they may be useful. Tentative suggestions for city planners and policy makers are offered to stimulate a discourse on how the capabilities of these vehicles can best be harnessed to foster sustainable and inclusive cities.

Introduction

Ongoing advances in affordable power electronics (such as [1]), lithium ion batteries [2], permanent magnet synchronous motors [3], and gyroscopic sensors have permitted the emergence, and enthusiastic initial uptake [4], of a plethora of new portable, personal electric vehicles [5], [6], sometimes called rideables [7]. For instance, vehicle such as motorised skateboards [8], scooters [9] and self-balancing unicycles [10] are each seeing increasing commercial success. Commenting on personal electric vehicles in 2005, Ulrich [5] could legitimately observe that "the full potential of the category has not been realized, to a large extent because the vehicles are not yet light enough, do not go far enough, and cost too much" The present work contends that, in the intervening years, each of these limitations – weight, range and cost – have been addressed, and, accordingly, these vehicles are now poised to realise their "full potential" as enablers of cost effective and energy-efficient personal mobility in urban environments. A key enabler of this upgrade in capabilities is the emergence of affordable lithium ion batteries: for instance, work in [2] demonstrated how lithium ion battery prices declined sharply over the period from 2005 to 2015, with the cost of one kW.hr of energy storage declining from approximately $1300 to $400 over that decade. Incremental yearly gains in battery chemistry have accumulated, so that costs and energy densities are now sufficient to underpin a new generation of affordable personal transportation devices. This paper will take its cue from [11], which recently commented "it is still unclear what kinds of established forms of transport [ridables] will replace and what new kinds of transport they will contribute to." The present work seeks to address this uncertainty, and will articulate how the ability of ridables to augment existing public transport offerings represents one of their unique distinguishing features. The synergies between these vehicles and existing public transport infrastructure will be a key theme addressed, as these devices are uniquely well suited to addressing the first- and last-mile problems for commuters. Three vehicle categories were considered in [5]: "Stand-on scooter","Sit-on cycles" and "Mobility scooters". In his concluding comments about these early ridables, Ulrich stated: "suppliers have not yet arrived at a set of practical vehicles that best match technical feasibility and consumer demand" 2 The present work contends that, since then, the various suppliers have risen to this challenge, with exciting new vehicle categories such as the previously-mentioned electric skateboards, self-balancing unicycles & dicycles eliciting growing consumer uptake in this segment. These vehicles sit within a paradigm of flexible mobility, where digital technologies such as ride hailing apps and bikeshare services are displacing the need for private car ownership in dense urban areas. Commenting on this trend, the authors of [12] noted: "There is a strong indication that the close link of modernity and private car use is beginning to dissolve, and new attitudes towards urban mobility that make use of variable modes of transportation are evolving" To provide the groundwork for this vision of flexible mobility, the present paper will survey the capabilities of the currently available rideables. Within this survey, the characteristic strengths and weaknesses of each vehicle type will be articulated. A key contribution of the work will be an attempt to quantify the value proposition for these technologies, by estimating the available scope for daily time and cost savings using existing data on commuting modalities. The work will conclude with suggested recommendations for urban planners and policy makers, to contribute to the emerging conversation on how these vehicles can be embraced to lessen car dependence in increasingly smart cities.

Conclusions

An accumulation of incremental technical advances have facilitated the emergence of light, portable, stable and rapid personal transport devices. While some may perceive these ridables as being mere novelties, or a fad, the present paper has used two case studies to clearly articulate the real value proposition that they offer. Crucially, these ridables are compatible with public transport, and so address one of the key shortcoming of traditional bicycles. By ameliorating the last mile problem, ridables tangibly enhance the attractiveness of public transport, and this work has suggested various ways that urban planners and policy makers can grasp this nascent opportunity to reduce car dependence.

Summary Statements:

1. "Ridables" are light, portable, and able to transport a single passenger through an urban environment.
2. These "Ridables" are able to go further and have more features; these factors are mutually dependant.

3. These vehicles are small enough to carry onto public transit.
4. The thesis aims to give a brief overview of different kinds of "Ridables", and estimate it's impact on urban commuters who may use them.
5. The thesis aims to discuss how these vehicles can encourage sustainable and inclusive environments to thrive in urban areas.
6. There are different styles of "rideable" and the industry is continuing to grow.
7. The full category of these kinds of vehicles are not realized yet.
8. These vehicles are becoming a more attractive option to consumers; both financially and functionally.
9. The thesis discusses three vehicle designs; "Stand-on scooter", "Sit-on cycles", and "Mobility scooters".
10. The thesis references an article discusses the decrease of interest in private vehicles.
11. This thesis [1] "[concludes] with suggested recommendations for urban planners and policy makers"
12. States that these vehicles can be considered better than traditional bicycles that since these vehicles are compatible with public transit.
13. States that these means can "tangibly enhance" the appeal of public transportation methods.

Key Article 2

Method

Search Engine: Google Scholar

Key Words Used in Search: “Review Electric Longboard”

Findings

Citation: SÖDERGREN, L. (2018). Electric Longboard : A dual-purpose personal vehicle (Dissertation). Retrieved from http://urn.kb.se/resolve?urn=urn:nbn:se:kth:diva-233145

Key Content:

Abstract

Keywords: mechatronics, personal transportation, electric vehicle, last mile transport, adaptive power management. The aim of this thesis is to explore the possibility of a dual-purpose electric vehicle. The vehicle should be able to be used for both commuting and racing. It also aims to describe different power limiting methods and their effect on performance. Lastly it hopes to see if the Swedish laws, as written today are reasonable. An electric longboard has been constructed for this purpose and several tests have been performed. A list of goals were set up for the board prototype. These included power output, running time, and that the board should have an audible warning device. The findings demonstrated that all tested power limiting methods worked and that the “Simple power limiting” method provided quickest movement over a fixed distance. Most of the goals were met by the prototype and the board’s two modes worked as planned. While the law is reasonable it can be improved to cover the diversity of electric vehicles. Further work may include better measurements and implementation of a dual microcontroller system.

Introduction

The purpose of this thesis is to explore the possibility of a dual purpose electric vehicle. The vehicle should be able to be used for both commuting and racing. It will examine different methods of power management to follow the above noted laws and regulations. Other aspects of this thesis will be the construction of a safe, user friendly vehicle prototype, while still providing adequate performance. The thesis hopes to examine the following questions:

• How do different power limiting methods affect performance?

• What methods of power limiting are possible?

• Are todays laws and regulations reasonable?

• How can a street-legal board be constructed?

Conclusion

From the list of personal goals this is what was achieved:

• Maximum speed (street mode): 20kmh, 5.56m/s. Not implemented, however the average speed of both commutes were under this limit.

• Maximum continuous motor power (street mode): 250w. Implemented and working.

• The board must be able to brake at 3m/s2 . The braking system should be functionally safe during normal operating conditions. Worked at higher speeds.

• The board should have a parking brake that can keeps the board stationary on a 15° incline, even without electrical power. This brake should not be a danger to the user if accidentally engaged. The parking brake was not able to hold the board. Flipping the board over proved more than adequate.

• The board should have white lights forward and red lights backwards that can be clearly seen from 300m. The lights cannot be blinding or must be able to be dimmed quickly. Implemented and working.

• The board should have an audible warning device (AW-dev). Implemented and working.

• The board should be able to monitor the batteries to allow safe usage. Partially implemented.

• The board should be able to run at full power (street mode) for at least half an hour. Technically possible more tests needed.

• The board's components have to be protected from the environment. Needs improvement. The project has shown several possibilities for a street-legal longboard. It shows the possibility of a dual-purpose vehicles and provides a method of giving feedback to the user. It shows that the law as it is written today is reasonable but could be improved for different sizes and types of vehicles.

Summary Statements:

14. Proposes a possible "dual-purpose electric vehicle" use for commuting and racing following then current Swedish laws.
15. Thesis consists of the construction of a working prototype with considerations to user safety and ease of use.
    i. Searches for the possible methods of artificially limiting power output.
    ii. Questions whether current laws and regulations are reasonable.
16. Board should have a parking brake that can keep it stationary on a 15° incline.
17. Board should have lights on the front and back that can be seen from a 300m distance.
18. Board should have an audible warning device (AW-dev)
19. Boards components have to be protected from the environment
20. This opens up the possibility of street-legal longboards

SELECTED TOPIC

a) Research Question (How may we…?):

How may we improve safety for Last Mile Vehicle (LMV) operation?

b) Briefly explain what you know about this topic:

I've been using Last Mile Vehicles (both electric and manual) for navigation around cities, university campuses, and urban areas for several years. I've noticed that as more and more cities begin accommodating for these vehicles, as many companies have begun offering new and innovative ways to provide commuters with LMV of various shapes and sizes. Several close friends and professional peers have used these sorts of vehicles to get around. I also have spoken to many industry experts who are on the cutting edge of the industry about the current landscape; from safety of operation, to where these products are going. I have also experienced my fair share of accidents while riding LMV, and I've found that current ways of preventing injuries are not keeping up with the speed, prevalence, and the technology of this transportation.

Another aspect often overlooked is the safety and security of both pedestrians and other vehicles that share the road with riders. The solution I will research for this topic will incorporate safety precautions for those operating the LMV, while also making their presence and intended path clearer to those who may underestimate the speed and abilities of these vehicles.

c) Why did you choose this topic as one of the top three?

Over the past two summers while studying and working in California, I decided to limit my dependence on traditional means of personal transportation. This choice was initially spurred on due to the financial savings I would benefit from, but quickly became something that I grew to appreciate and enjoy as an alternate method of getting around an area; be it urban, or a collage campus. I found that the best use for these vehicles were when they were used in tandem with public transportation, giving the term "Last Mile Vehicle" credence.

Although the other two topics I considered are important in their own ways, I found that this topic was something that resonated more with my lifestyle than the other two. I personally believe that the future of urban commuting is a combination of public and private transportation. As more major cities are turning to LMV adoption (rental bikes, skateboard/longboard racks), there is a clear and present need to incorporate more contemporary means of protecting the rider, pedestrians, and other vehicles; both traditional, and autonomous.

d) Selection and Justification of your Thesis Topic (Single topic)

Based on the feedback provided for the three topics presented in Week 2, select **ONE** single thesis topic you plan to pursue.

- **Initiate preliminary research into your selected subject. This investigation forms an initial component of your Thesis Report, and will include images and reports (academic papers and white papers) of the following:**

Context: User Profile (primary, secondary, tertiary users as applicable)

Context: Environment of use

Context: Benchmarked products (existing products)

The above content is critical as part of this Phase.

Tabulate the questions raised for challenges of each sub-domain as follows:

User (current challenges for primary, secondary and tertiary user) *- Indicate a minimum of 10 items*	*Product (current challenges of benchmarked products)* *- Indicate a minimum of 10 items*	*Environment of use (current challenges of various environments of usage);* *- Indicate a minimum of 10 items*
Lack of enforceable	*Lack of speed/input*	*Lack of protected/tiered*

safety regulation: - *No license required to operate or purchase vehicles.* - *No set laws in place for riders.*	*standards:* - *Method of operating vehicle depends on manufacturer, no standard.* - *Speed of LMV is dependent on the manufacturer, no standard.*	*lanes:* - *No separate "LMV Lanes" similar to bike lanes.* - *No distinction between fast/slow lanes.*
Lack of rider restrictions: - *No widespread age restriction.* - *No consideration for accessibility limitations, disabilities.* - *No age limit for operation or purchase.*	*Lack of personalization:* - *Current methods of personalization may void warranties.* - *Many customization options are limited to function rather than aesthetic.*	*Lack of consistent riding conditions:* - *Irregular riding conditions.* - *Often blocked or obstructed in urban areas.* - *Side of road is often curved in for sewer drains..*
Lack of a safety standard system: - *No manufacturing standards in place for these vehicles.* - *No safety quota or consistent manufacturing protocol for vehicles.*	*Lack of operational guidelines (area of use):* - *LMV can currently be used only on roads, but their portability doesn't stop riders from using sidewalks or other pedestrian pathways.*	*Lack of established connection with other commuter vehicles:* - *No set method of interaction/ signaling between LMV riders and other commuters (cars, trucks, busses).*
Lack of adequate safety equipment: - *Current safety*	*Lack of connectivity between vehicles:* - *Riders are unable*	*Lack of proper classification as a vehicle:*

methods (Helmets, kneepads) are not adequate to protect the rider in case of high-speed accidents. - *This safety equipment is designed solely for the benefit of the rider, not other vehicles.*	*to notify vehicles (autonomous or traditional) of their presence, speed, or movement.*	- *Unable to be registered in a user database rather than a private companies' server.* - *No distinct classification for each vehicle type/ capability.*
Often requires smartphone to activate: - *Overly reliant on the implied use of modern technology.* - *Barrier of limitation to users who may not own (compatible) smart devices*	*Lack of "frictionless" use:* - *LMV may be difficult to combine with public transit due to size + weight variables.*	*Lack of prevalent charging/housing bays:* - *Often rely on commercial plugs to charge devices during commute/ no charging standard.* - *Public vehicles are often deserted after use, acting as a hazard and obstacle.*
Unsanitary when used by multiple users: - *Public LMV can be used/ interacted with anyone on the street.* - *Materials used often can house bacteria.*	*Lack of range (battery life):* - *Owners and riders are actively unaware of their current battery life at a notice, rather are alerted when it's low or must manually check.*	*Lack of repair tools/depots:* - *Difficult to repair without involving manufacturer warranty services.* - *Lack of standard parts, difficult for non-hobbyists to easily customize*
Fragmented ecosystem	*Lack of repair standards* - *Due to warranty*	*Lack of proper road*

can prove to be confusing: - *No standard for UX/UI across vehicles.* - *No standard "Ride Feel", speed, or preference.*	*reasons, owners are unable to safely and easily repair vehicles, rather having to rely on the manufacturer.*	*signage:* - *Other commuters are unable to prepare for introduction of LMV onto the shared road.*
Risk of higher speed collisions: - *Rider x Rider* - *Rider x Pedestrian* - *Rider x Traditional vehicle*	*Lack of preventative safety technology for riders:* - *Most products available currently rely on active protection (impact or fall) rather than preventative (alert system.*	*Non-standard topology:* - *Road debris, unfinished or damaged asphalt prove hazardous to riders.* - *Differences in ground texture makes for an uneven commute using LMV*
Often silent: - *no means to alert pedestrians or commuters of presence*	*Lack of innovative material use in safety solutions:* - *Current safety methods are single use and unrepairable.*	*Difficult to navigate far distances:* - *City layout makes it difficult to safely travel longer distances.*
General disapproval from motorists/cyclists: - *"Too fast for bikes, too slow for cars"*	*Lack of comfort for extended trips:* - *No storage space available in most vehicle types.* - *Safety products can be intrusive and bother the rider during longer trip.*	*Lack of city planning:* - *Current urban cities are built to accommodate traditional vehicles, bikes, pedestrians, and are being disrupted by LMV use.*

- **Based on the USER - PRODUCT- ENVIRONMENT OF USE triangulation, write a 150 – 200 - word "justification" of the selected Thesis Topic**

The selected Thesis Topic requires consideration for many factors that are dependent on not just the rider, but also those who will share the road with them, and pedestrians. The current bar of entry for LMV adoption comes from a lack of proper regulation (both safety and operation), which could act as a deterrent for prospective users. That means that extensive research will need to be conducted on areas outside the solution design itself. Not enough research has been put into making these diverse vehicles any safer. There is a need for proper, standardized security protocol to be designed and implemented based on research, ergonomic factors, and requiring multiple interaction points on the users body; thus meeting the criteria of the Thesis.

e) **Explain how this thesis proposal contributes to the following four thesis values: enhancing the quality of human life; full-bodied human interaction design (FBHID); ergonomics, user experience, convenience of use; sustainability and social responsibility.**

This should be a single paragraph (150-words) which explains the following:

- *Motivation/Problem statement: Why do we care about the problem? Incorporate the What, Why and How to frame your description*
- *Description of the Primary, Secondary and Tertiary user (if applicable)*
- *Provide a clear description of topic chosen; clear goals, scalability of the design solutions to other domains*
- *Opportunity of the depth (possibility of in-depth study of FBHID) and breadth (possibility of distinctly different concept directions) of the topic proposal*
- *Reasonable potential to meet all four thesis selection assessment criteria*

As Last Mile Vehicles increase in speed and prevalence, there is an abundant lack of innovation with the safety equipment meant for the rider. Since these vehicles are becoming a major contestant to traffic congestion, there is a growing need to keep commuters, drivers who share the road with them, and pedestrians (primary, secondary, and tertiary users respectively) safe. Since the topic is dealing with improving the safety of those who operate LMVs, the solution would need to be available and deployed to a wide number of users in an ergonomic, considerate way. This can take the form of unobtrusive products (or a series of products) paired to the method of travel, or even factoring in the design of the vehicle itself. With safety factors, research will need to be done on established safety regulations, as well as higher risk injuries obtained while operating these vehicles. Preventing any kind of distraction or bulk will also be a design challenge, meaning weight, UI, and size will also be an important factor of the design.

Appendix II – User Research

Abstract

This report consists of interviews conducted on two Last Mile Vehicle (LMV) riders discussing their experience using their vehicles, use of safety/accident prevention products, and their vision of the future of LMV operation. Each interview was carried out at separate times and within separate contexts. The first interview involved a user who has purchased their own LMV, while the second interview involves someone who rents a vehicle from an automated public rental kiosk. Each product interview concludes with a reflection and key take-away points from the interaction. By conducting user interviews, we were able to gain further insight on the needs of our prospective users that can be considered when designing our thesis solution. Both interviews were conducted based on a prewritten set of 12 questions designed to encourage further discussion by the two users.

Keywords: user interview, product design, contextual insight.

Method

Interviews were conducted in person and responses were recorded as the interview was happening. Notes are added to provide context for how the user reacted when asked a question, and a description of the time + place was recorded. Users were also asked to respond as honestly as they could in order to record genuine reception. The process of finding interview subjects involved travelling downtown and observing prospective participants. The first interview was conducted on the TTC (Toronto Transit Commission) subway system while the second interview was conducted while the user was renting a vehicle from an automated public bike share station. By capturing rider feedback in a natural setting, conducting the interview was a seamless interaction, and helped ease any tension that may have been felt by the interviewees.

Interview Questions

1. What kind of Last Mile Vehicle do you use? How long have you been riding?
2. What do you primarily use it for?
3. How often do you use safety gear when you ride? What do you use?
4. Do you primarily ride on the bike lane or between vehicles?
5. Have you been in or witnessed any accidents while riding? What happened?
6. Have you ever felt “uncomfortable” or “out of place” when riding with other vehicles?
7. What are your biggest concerns while riding?
8. Tell me about a time where you didn’t feel safe while riding in “less than optimal” conditions?
9. What would you change about the riding experience of your LMV?

10. What information do you wish you could convey to other riders/drivers around you?
11. What do you want to see being added to your vehicle in 10-15 years?
12. Anything that I haven't brought up that you wish to add?

Interview 1

Background

Name: Hassan Basaleeb

Email: hassanbasaleeb@gmail.com

Occupation: Student, Uber Eats courier

Date: Friday October 4th, 2019

Time: 10:00 PM

Location: TTC subway, Northbound from Bloor to Sheppard-Young station

Vehicle: https://emmo.ca/emmo-monta

Interview Method: Face-to-face, transcribed on phone (text)

Transcript of Interview

[While taking the subway uptown after an evening with friends, I noticed Hassan enter the subway car with an e-bike. After asking if he had time for an interview while riding the train, he enthusiastically agreed.]

1. **What kind of Last Mile Vehicle do you use? How long have you been riding?**

"I've been using this [gestures towards his bike, a "Monta" by Emmo] for almost two years. I bought it second hand on 'Kijiji' (an online, second hand marketplace)."

2. **What do you primarily use it for?**

   "I bought it to deliver food for Uber Eats, I don't use it for much else since I live near the subway station and can get to school from there pretty easily. I only take it out on days that I work."

3. **How often do you use safety gear when you ride? What do you use?**

   "[He laughs when I mention I didn't see him wearing a helmet], I only wear a helmet on weekends, or if I know traffic is going to be really busy. I should probably wear it more often! I don't wear anything else other than the helmet."

4. **Do you primarily ride on the bike lane or between vehicles?**

   "A little bit of both, I occasionally must go between vehicles, but I tend to stick to the bike lanes. Sometimes the bike lane is obstructed so I must dip into the main road. It's dangerous, but I make sure to let drivers know I'm joining them."

5. **Have you been in or witnessed any accidents while riding? What happened?**

   "I haven't had any close calls or accidents, nor have I seen any. Sometimes I get honked at if I must join the road, but nothing too bad. I make sure to ride safely."

6. **Have you ever felt "uncomfortable" or "out of place" when riding with other vehicles?**

    Sometimes when I'm riding near cars or other vehicles. Mainly about my stability. Especially if there was or is rain."

7. **What are your biggest concerns while riding?**

    "Probably will have to be the pedestrians that get in the way. They cut in front of me or stand in the bike lanes which can often be dangerous."

8. **Tell me about a time where you didn't feel safe while riding in "less than optimal" conditions?**

    "I'm usually concerned when it just rained or if it's raining. Mainly for the way it affects my tires and cargo [pantomimes an "Uber Eats delivery bag" on his back."

9. **What would you change about the riding experience of your LMV?**

    I would add mudguards to my bike to make it easier to go in messier conditions [points to the debris caught in his tires], it can really become a problem fast. Anything that stops this. I wouldn't mind a larger battery, but I don't need to charge too often [mentions how he charges every night like his cellphone]"

10. **What information do you wish you could convey to other riders/drivers around you?**

"I wish I had turn-signals and a break light, something to let people know where I'm going or if I'm going to slow down. I also wouldn't mind having better lights for night deliveries. Something that can make it safer for me, cars, and pedestrians."

11. What do you want to see being added to your vehicle in 10-15 years?

"[Laughs] Honestly, another wheel to make it more stable and comfortable. My friends recommend scooters because of their size and comfort."

12. Anything that I haven't brought up that you wish to add?

"[Thinks for a few seconds] Nope, I think you asked anything I could think of. Thanks!"

Discussion

Reflection

Although it was very kind of Hassan to let me interview him on a busy subway car, I would probably investigate conducting the interview at a later time or place as to avoid having to speak over the ambient noise that surrounded us. I would also conduct the interview sitting down for a more comfortable conversation to take place. However, I feel that the interview came off as more natural since it was conducted in a location that is more "relevant" to LMV usage.

Key Points

- Hassan's LMV was primarily used for food delivery. His choice of vehicle was dictated by the company of which he is contracted (Uber Technologies Inc.) as they offer the choice of car or bike food delivery (depending on location).
- Hassan's largest concerns were his interactions with the tertiary customer (pedestrians) rather than the secondary customer (vehicles).
- Hassan chose to wear safety equipment based on extraneous circumstances (rain, busier roads) rather than a concern for his personal safety on a day to day basis.
- Hassan wishes for an easy way to indicate movement intentions (brake lights, turn signals) and to make his presence more known to pedestrians (headlight system).
- Hassan emphasized comfort as a major importance to riding his e-bike.

Interview 2

Background

Name: David Runesha

Email: rudavid10@gmail.com

Occupation: Student

Date: Wednesday October 5th, 2019

Time: 1:45 PM

Location: 351 Bloor Street W, Toronto Ontario

Vehicle: Bike Share Toronto Rental Bike

Interview Method: Face-to-face, transcribed on phone (text)

Transcript of Interview

[As soon as I exited St. George Station, I began looking for a public bike rental station to wait by in the hopes of conducting an interview. As soon as I began to cross the street, I noticed a rider arrive on a rented bike. I asked if their destination was nearby and if I could ask them a few questions.]

1. **What kind of Last Mile Vehicle do you use? How long have you been riding?**

   "I started using the rental service about a month or two ago. I normally have my own bike but it's not here, I'm originally from Chicago."

2. **What do you primarily use it for?**

   "I'm a student at University of Toronto, currently studying Econ + Stats. I use it primarily for transportation around the city. I was actually on my way to get groceries just now. Paying $100 a year for unlimited bike access beats driving a car around. It doesn't make sense to own a car in the city.

3. **How often do you use safety gear when you ride? What do you use?**

   [I remarked that he didn't have a helmet, he laughed] "Yeah, I usually wear a helmet when I go on further trips, anything outside of the metro area. When I go biking with my family (for sport, not leisure), I wear a helmet and pads. Outside of that I don't like the feel of it when running a quick errand. Feels constraining."

4. **Do you primarily ride on the bike lane or between vehicles?**

"Bike lane. Drivers are crazy downtown."

5. **Have you been in or witnessed any accidents while riding? What happened?**

   "Thankfully not, but I have seen the aftermath of these accidents. Lots of broken parts abandoned on the side of the road."

6. **Have you ever felt "uncomfortable" or "out of place" when riding with other vehicles?**

   "Only when there is no clear bike lane. Drivers are quick to anger if you slow them down. I become very cautious whenever I am on those sorts of streets."

7. **What are your biggest concerns while riding?**

   "Cars. Hands down. Especially trying not to get hit by any [laughs]. Also, pedestrians, but not as much. If anything, I am more of a hazard to them on the road. Sometimes they cut in front of me or jaywalk."

8. **Tell me about a time where you didn't feel safe while riding in "less than optimal" conditions?**

   "Sometimes when it rains my pedals get a bit slippery and the seat is kind of gross [laughs]. I need to pay more attention when that happens. I wear a helmet when rain is expected, or if it rained the day before."

9. **What would you change about the riding experience of your LMV?**

   [When I asked him this question, I also inquired about his rental experience and what he would change about that] "I notice that there is an "eb and flow" when it comes to renting these bikes. In the morning It's easy to find a bike, but harder to dock it. At night, I have to travel a lot more to find one. [I asked him if there is a dedicated app to find bikes] Yeah! I use it only if I can't find one. Would be nice if I was able to know that there will be a bike without having to hunt one down."

10. **What information do you wish you could convey to other riders/drivers around you?**

"When I ride around other bikes, there seems to be a universal set of signals that we use and understand [rings the bell on his bike] we usually just do that to alert each other that we are in proximity. It's much harder to signal this to drivers. Even I have a hard time recognizing a bike riders' intention when I'm behind the wheel. I wish I had turn signals ON my bike rather than hoping they catch my vague signal.

11. **What do you want to see being added to your vehicle in 10-15 years?**

"Built in signals, something that tells people I'm slowing down. Also, a more comfortable ride. The seat becomes a pain after a while."

12. **Anything that I haven't brought up that you wish to add?**

"Not really. I guess I just want to say that I love the affordability of this program and how easy it is to get what I need to do done. I like the fact that there are a lot of these stations around for riders to use. Super convenient."

Discussion

Reflection

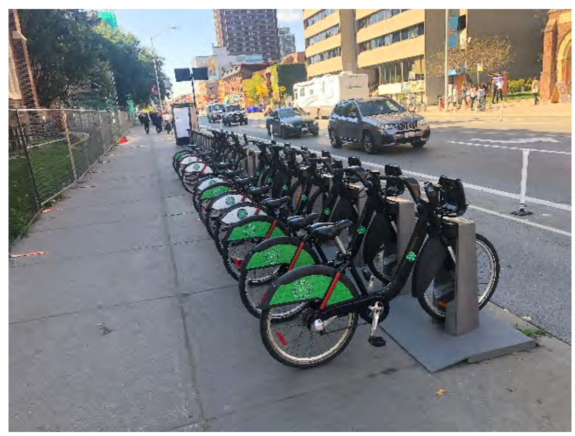
Overall, I was happy with the interview. David was obviously passionate about the bike rental service and enjoys the idea behind it. The information that he provided was useful in being able to understand use cases of people on these bikes. Ideally, I would have inquired about his experience with the application and where there would be improvements, but I did not want to take too much time away from his errand.

Key Points

- These vehicles are already outfitted with reflectors and lights. This improves the rider's comfort while operating the vehicle at night.
- David was a fan of the affordable and ease of use surrounding the use of public LMV programs.
- David felt hindered by existing safety equipment while operating his LMV. Although he did see the benefits behind using them.
- David recognized the lack of proper signaling between LMV riders and cars. He appreciated the unspoken alert of the bell and its significance in alerting other bike riders of his presence.
- David remarked on the downside of operating public vehicles after a rainfall (slippery pedals, wet seats).

Images

Hassan with his e-bike on the TTC



Left: David with a "Bike Share Toronto" bike

Right: "Bike Share Toronto" bike rental station

Conclusion

Interviewing two distinct yet similar users proved to be insightful to gaining a broader understanding of how end users ultimately operate their choice of LMV. Using these vehicles as alternatives to traditional modes of transportation (cars), or in tangent with existing public methods subway) can prove to be more convenient and financially viable to navigate within metropolitan areas. By carefully crafting questions, interviewees were encouraged to add their own personal insight to the dialogue; providing a unique and personal touch to the recorded conversation.

Methods

In order to research primary, secondary, and tertiary users to generate profiles, a series of parameters will need to be put in place. For the context of this report, the list of users will be:

- Primary users: LMV riders
- Secondary users: Other commuters sharing the road.
- Tertiary users: Pedestrians

By using key search terms, demographic information will be observed and will help generate these profiles. Metrics like age, gender, and profession will be factored into these personas. The common link between these users will be their use of LMV devices in their day to day lives. Evidence will be drawn from image searches of users interacting with products, as well as literature discussing trends and use cases for these riders.

Evidence

In order to find evidence of Last Mile Vehicle Riders, certain searches will need to be made in order to obtain a "look and feel" of the demographic of riders. This will assist in further demographic research.

Keywords used:

- 1. Last Mile Vehicle Rider
- 2. Last Mile Vehicle Rider + City
- 3. Last Mile Vehicle Rider + Campus

Description + Notes	Image + Title	Reference
Male + Female rider on rental scooter. - Brand: Bird - Not wearing helmets - Early to mid 20s - Using cellphone while riding	 Bird electric scooter riders in Santa Monica, California. Photograph: Dan Tuffs/The Guardian	Carroll, R. (2018). *Are ride-share electric scooters the future of urban transport?*. *the Guardian*. Retrieved 26 September 2019, from https://www.theguardian.com/cities/2018/apr/25/electric-scooters-urban-transport-bird-santa-monica-uk
Male + Female riders on Unicycles - Taken in France during “Paris without cars”, a day encouraging the use of alternate modes of transportation - All riding the same vehicle (electric unicycles) - Mid to late 20s - One out of ten wearing a helmet	 Self-balancing unicycles at 'Paris sans Voiture' (Paris without cars), September 2015.	*Electric unicycle*. (2019). *En.wikipedia.org*. Retrieved 26 September 2019, from https://en.wikipedia.org/wiki/Electric_unicycle
Male commuter riding scooter past a row of public bikes - Rider in bike lane - Using a helmet - Late 20s early 30s - Well dressed.	 Micro-mobility	Let’s Go for a Spin: Ford Buys Scooter Company to Provide Customers a First-Last Mile Solution *Let’s Go for a Spin: Ford Buys Scooter Company to Provide Customers a First-Last Mile Solution*. (2018). *Medium*. Retrieved 26 September 2019, from https://medium.com/cityoftomorrow/lets-go-for-a-spin-ford-buys-scooter-company-to-provide-customers-a-first-last-mile-solution-bbeae278d373

Production shot for LMV company (URB-E) - Both riding same vehicle - Waiting at metro stop - One user (male, mid 20s) has LMV folded - Other user (female, mid 20s) resting on stationary vehicle	 LA Metro has approved the URB-E for use on Los Angeles public transportation	LA Metro Loves URB-E Electric Scooters *LA Metro Loves URB-E Electric Scooters*. (2016). *URB-E*. Retrieved 26 September 2019, from https://urb-e.com/blogs/news/la-metro-loves-urb-e-electric-scooters
A group of students riding a variety of different transportation methods - Riders look late teens, early 20s - Riding scooters, “hoverboards”, and a electric skateboard - One rider has a helmet	Save yourself a few steps with electric transportation. Josh Miller/CNET	Hollister, S. (2019). Hoverboard, skateboard or scooter: which is the best last-mile commuter?. Retrieved 26 September 2019, from https://www.cnet.com/news/electric-scooters-are-amazing-last-mile-transportation/

Notes:

- Average age of riders is 23-26
- Majority do not use helmets
- Majority use in Urban areas or college campus
- Use in tandem with public transit

- Limited regulatory concerns about operation (most using vehicles in the street, no protection)

Demographic Literature search:

In order to produce further evidence of Last Mile Vehicle Rider demographics, Google Scholar and the Humber library were used to search for articles related to LMV rider demographics.

Keywords used:

- 1. Last Mile Vehicle Demographics
- 2. Electric bike market research

Literature Search results:

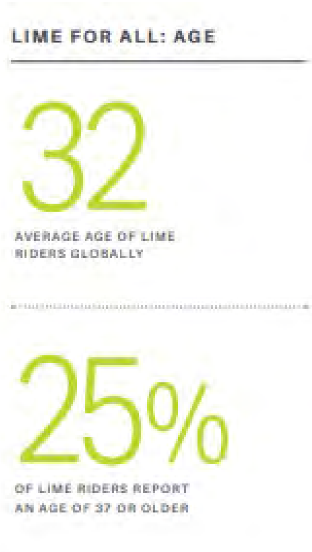
Cherry, C., Yang, H., Jones, L., & He, M. (2016). Dynamics of electric bike ownership and use in Kunming, China. *Transport Policy*, *45*, 127-135. doi: 10.1016/j.tranpol.2015.09.007

Lime. (2018). *Lime 2018 Year-End Report*. Retrieved from https://www.li.me/hubfs/Lime_Year-End%20Report_2018.pdf

populus.ai. (2018) (Measuring, 2018). *Measuring Equitable Access to New Mobility: A case study of shared bikes and electric scooters*. Retrieved from https://research.populus.ai/reports/Populus_MeasuringAccess_2018-Nov.pdf

populus.ai. (2018) (Micro, 2018). *The Micro-Mobility Revolution: The Introduction and Adoption of electric scooters in the United States*. Retrieved from https://research.populus.ai/reports/Populus_MicroMobility_2018_Jul.pdf

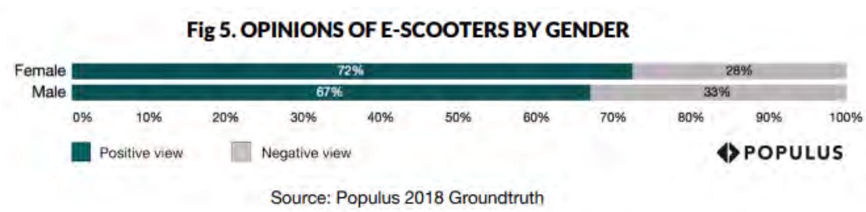
Age + Gender:



Lime age demographic, Global (Lime, 2018)

"Between 2006 and 2012, gender is relatively evenly split, with some increase in the percentage of male respondents. The average age is about 32 years old." (Cherry, 2016)

Consistent with electric scooter adoption data, we also find that slightly more women have a positive view of electric scooters than men (see Figure 5). This early data on e-scooters provides evidence that newer, micro-mobility services might achieve greater gender parity than previous station-based bikeshare systems have. (Micro, 2018)



Summary:

Demographics of LMV Riders		Reference
Age	<32	(Lime, 2018) ; (Micro, 2018)
Gender	52% Men to 48% Women. Close to tied	(Cherry, 2016);(Lime, 2018);(Micro, 2018)
Ethnicity	Global adoption	(Micro, 2018);(Lime, 2018)
Educational Background	High school or college education	(Cherry, 2016)

Overall, User Demographics for LMV tend to be an average of 32 split between men and women. The majority of which are middle class and have a high school education. The majority of images found regarding LMV riders involves younger users. This could reflect in the data observed as these methods of transportation are significantly less expensive then owning a vehicle. As the average age of LMV rider is reported as 32, it can be assumed that this is a contributing factor to the “middle class” demographic trend that’s observed. Obtaining a source from the Chinese market (Cherry, 2016), we can observe this user demographic among the two larger global markets.

Ethnicity

1) the adoption rates for dockless services have surpassed the adoption rates for the Capital Bikeshare system;

2) the Black and African-American population (which represents 47% of the entire D.C. population) has adopted dockless services at a significantly higher ratio: 2.6 times more versus 1.2 times more (see Fig. 3). (Measuring, 2018)

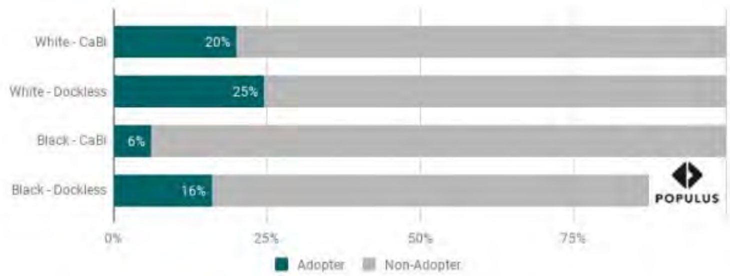


Figure 3. Adoption rates of micromobility services in Washington D.C. by race.

Education and Income:

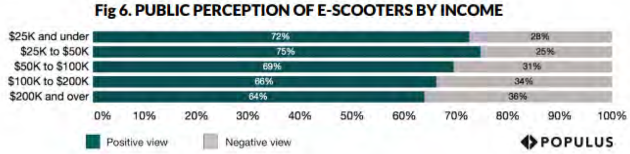
Table 1
Demographics of respondent e-bike users.

Year	Sample size	Individual characteristics				Household characteristics			
		% Male	Age	Monthly income (RMB)	% College degree	Yearly income (RMB)	Adults	Working adults	Child
2006	303	49	33.1 (9.6)	1930 (1165)	20	41,637 (27,337)	2.9 (1.1)	2.4 (1.1)	0.6 (0.6)
2008	597	52	32.5 (9.5)	2258 (1138)	31	66,190 (33,801)	3.1 (1.4)	2.4 (1.0)	0.6 (0.7)
2010	515	59	30.5 (10.2)	2535 (1395)	24	60,242 (34,879)	3.3 (1.5)	2.5 (1.2)	0.5 (0.6)
2012	801	57	31.7 (9.7)	2921 (1343)	23	67,937 (39,532)	3.1 (1.3)	2.4 (1.3)	0.6 (0.7)

1. Standard deviation in parenthesis.
2. Average Incomes are estimated from mid-points of income categories.
3. Primary Income Earner status is applied if individual contribution to the household income is greater than the average share of all working adults in the household.
4. Income questions refer to year previous of survey.
5. $1 = 8.00 RMB (2006), $1 = 6.80 RMB (2008), $1 = 6.75 RMB (2010), $1 = 6.30 (2012).

(Cherry, 2016)

Fig 6. PUBLIC PERCEPTION OF E-SCOOTERS BY INCOME



Source: Populus 2018 Groundtruth

Average age 32

Average income: Middle Class

68k RMB ($13k CAD). Considered "Middle Class"

23% have college degrees

(Micro, 2018)

User Behavior

Literature Search Results:

Lime. (2018). *Lime 2018 Year-End Report*. Retrieved from https://www.li.me/hubfs/Lime_Year-End%20Report_2018.pdf

MacArthur, J., Dill, J., & Person, M. (2014). Electric Bikes in North America: Results of an Online Survey. Transportation Research Record, 2468(1), 123–130. https://doi.org/10.3141/2468-14

Reason of Use

(Lime, 2018)

(Lime, 2018)

(MacArthur, 2014)

Summary:

User Behaviour		Reference
Shopping + Entertainment	32	(lime, 2018); (MacArthur, 2014)
Commute to work + school	40	(lime, 2018); (MacArthur, 2014)
Replace trips with vehicles	30%	(lime, 2018); (MacArthur, 2014)

Overall the majority of trips using LMV are to and from school and as short, inner city commutes where a vehicle could have been taken but was opted out.

User Profile Summary

Demographics		**User Behavior**	
Age	<32	**Shopping + Entertainment**	31% - 35%
Gender	Male > Female	**Commute to Work + School**	30% - 34%
Ethnicity	Global	**Replace Car Rides**	30% - 40%
Educational Background	Highschool Student + Some University		

Overall, LMV users tend to be an average of 32 (majority younger), male, and majority students (post secondary). Much could not be found on the specifics of LMV usage amongst riders as this method of rideshare is relatively new. However, from information gathered from Lime's Yearly Report, the largest areas of use for this sort of vehicle involves short trips inside Urban areas, commuting to work or school or replacing car rides.

Persona

A potential user profile was created based on the metrics collected during research.

Name:	Brian Zhao
Age:	25
Job:	Part time retail + content creator
Income:	$45,000
Education:	Ongoing, University
Relationships:	Girlfriend
Location:	Palo Alto
Main Hobby:	YouTube content creator, photographer
Frequency:	Between lectures, work, and downtown.
Social:	Friend group from work and university
Other pursuits:	Fitness enthusiast, social + outgoing.

Daniel Dahlberg was riding his Boosted Board v2 down a hill in Kitsilano when he was stopped by police and fined $598 for riding a motorized skateboard on the road. https://vancouversun.com/news/local-news/vancouver-mans-first-ride-on-electric-skateboard-ends-with-600-ticket

Profile

Brian Zhao is a 27-year-old first generation Chinese American. He was born in Palo Alto and currently lives with his parents while finishing his second undergraduate degree in Computer Science. He works Part Time at the Apple Store at the nearby shopping center and has a relatively successful Vlog channel on YouTube. Cumulatively between jobs he earns $45,000.
Brian uses a Boosted Board to commute around campus, go to work after class, and head downtown on Fridays and weekends where he meets up with friends to go for drinks at the local pub.

Use Behavior

Brian uses his Boosted Board as his primary source of transportation. If the commute is too far, Brian combines the use of his board with public transit or ride sharing platforms like uber or lyft. He likes to get homework done in cafés off campus and uses his board to go to nearby locations, using the establishments wifi to stay connected and their outlets to charge his board. On longer trips to San Francisco, he rides his board to the train station to meet with his girlfriend. Once there, she rents a nearby bike and they ride to nearby parks.

Brian’s relationship with his LMV

Brian bought his board second hand on Craigslist. This was initially as an inexpensive way to commute around campus but turned into a hobby. He enjoys riding it around campus, enjoying the closed off privacy that his University affords him. He has been able to successfully repair his boards components by himself, and often goes to monthly meetups where he rides in a social group setting

Appendix III – Product Research

Figure 1 - https://www.amazon.com/Xiaomi-Electric-Long-range-Fold-n-Carry-Ultra-Lightweight/dp/B076KKX4BC

XiaoMi Mi Electric Scooter Pro

https://www.mi.com/global/mi-electric-scooter-pro

Last Mile Vehicle

Search (Google): 'Electric Scooter'

Description

The Mi Electric Scooter Pro by XiaoMi is an affordable, high performance motorized electric scooter. It is designed to be easily used in urban areas and alongside public transit. The Scooter can be folded easily to store and carry.

Specifications

Designed with a long lasting 474Wh battery, the board can travel 45km before requiring a charge. The scooter is capable of regenerative breaking, allowing it to recharge as users apply the break. Built in safety features include a bell, an 'ultra-bright' headlight, red tail break lights, and pneumatic tires that allow for easy transportation even in rougher terrain.

Figure 2 - https://store.segway.com/ninebot-by-segway-s-pro

Ninebot by Segway S-PRO

https://store.segway.com/ninebot-by-segway-s-pro

Last Mile Vehicle

Search (Google): 'Segway'

Description

A smaller iteration of the company's signature Segway vehicles, the S-PRO includes a more portable body as well as ambient lights for turning, breaking, and night riding. A high capacity battery pack allows this self balancing vehicle to run efficiently and push more power into the motor-integrated wheels. A knee guard improves comfort while riding, as well as a acting as a handle while transporting the device.

Specifications

The high capacity battery pack has an intelligent Battery Management System (BMS) which allows the vehicle to reach top speeds of 16 km/h. The 13 kg weight of the vehicle allows it to be easily carried on and off transit. A dedicated smartphone app leads to a more personalized ride, allowing users to control the vehicle and manage power consumption.

Figure 3 - https://onewheel.com/products/xr

OneWheel XR

https://onewheel.com/products/xr

Last Mile Vehicle

Search (Google): 'Electric One Wheel'

Description

Simulating the feeling of snowboarding, this single wheeled last mile vehicle boasts a single, motor containing tire that can travel smoothly over a variety of different surfaces. Built in front facing lights and brake lights make for a safer night ride.

Specifications

Vehicle is capable of travelling 12-18 miles on a single charge and can reach a top speed of 30 Kph. A 750W motor in an 11.5 inch tire makes this vehicle weigh 27 lbs.

Figure 4 - https://www.google.ca/glass/start/

Google Glass Enterprise Edition 2

https://www.google.ca/glass/start/

Heads Up Display

Search (Google): 'google glass'

Description

Based on their initial consumer grade Heads Up Displays, Google packs many of their automated assistants features into a portable, multi purpose camera/ projector system. This allows for information to be displayed in front of the wearers field of view.

Specifications

Running a custom build of Android Oreo, these touch gesture based glasses have interchangeable frames, a mono speaker, and an 8Mp wide angle camera. These are primarily based for enterprise solutions and can be used to assist on the job workers to access information without taking their eyes off the task at hand.

Figure 5 - https://www.vuzix.com/products/blade-smart-glasses

Vuzix Blade

https://www.vuzix.com/products/blade-smart-glasses

Heads Up Display

Search (Google): 'AR Heads Up Display'

Description

Unlike similar offerings from Google, the VUZIX Blade was designed for consumer use. They are built to primarily project relevant information to your view without the need of using your smart phone. This includes the ability to check notifications, fitness, and reply to messages hands free through the use of Amazon's Alexa voice assistant.

Specifications

The HUD glasses allow users to access most of their phones contents at a glance. The built in 8 megapixel camera allows for video and photography through the use of the side touch panel on the side. There are swappable lenses so that users can use their own prescription, and the optional Clip-On sunglasses allow users to view contents in brighter settings.

Figure 6 - https://www.microsoft.com/en-us/hololens/hardware

Microsoft HoloLens 2

https://www.microsoft.com/en-us/hololens/hardware

Heads Up Display

Search (Google): 'Enterprise Augmented Reality"

Description

A second iteration of Microsoft's revolutionary HoloLens from 2012, these smart glasses allow users to view and interact with content through the use of hand gestures and voice. The self-contained unit allows users to view content without the need of an external battery or processing pack.

Specifications

The six cameras affixed to the headset allows users to view holographic content with low latency. Real time hand and eye tracking allows for uninterrupted and unobtrusive interaction.

Figure 7 - https://atap.google.com/jacquard/

Google Jacquard

https://atap.google.com/jacquard/

Smart Commute Safety Equipment

Search (Google): ‘Smart Jacket”

Description

Released in partnership with Levi’s, the Jacquard is a jacket built with commuters in mind. The left sleeve of the jacket contains Google’s proprietary ‘threads’, a smart fabric that allows users to swipe or tap their cuff to do anything from changing music settings, to providing turn-by-turn navigation.

Specifications

Through a variety of lights and haptics, the Jacquard snap tag provides different contextual cues based on forms of notifications and input. The jacket is machine washable and made of Levi’s branded jean material

Figure 8 - https://www.helite.com/touring-grey-adv-rider-jacket-airbag

Helite TOURING Airbag Jacket

https://www.helite.com/touring-grey-adv-rider-jacket-airbag

Smart Commute Safety Equipment

Search (Google): 'Electric Scooter'

Description

Designed primarily for motorcyclists, the Helite TOURING Airbag Jacket uses a variety of gyroscopic sensors to trigger airbags that provide cushioning for riders who suffer a fall at higher speeds.

Specifications

Outfitted with a variety of pockets and zippers, the Helite Airbag jacket feels like a regular motorcycle jacket while also providing a higher sense of safety when user's fall off their vehicle.

Figure 9 - https://www.kickstarter.com/projects/491835187/crosshelmet-the-smart-motorcycle-helmet

CrossHelmet

https://www.kickstarter.com/projects/491835187/crosshelmet-the-smart-motorcycle-helmet

Smart Commute Safety Equipment

Search (Google): 'Electric Scooter'

Description

Having bypassed it's goal of $100,000 threefold on Kickstarter, this soon to be released smart motorcycle helmet is designed to provide an increased sense of comfort and security for motorcycle riders, as well as providing an attractive and futuristic aesthetic.

Specifications

With a built in heads up display, the CrossHelmet contains many different improvements to conventional motorcycle helmets. A wide angled rearview camera, ambient sound control, and a safety light keeps riders in the know of their surroundings. Ride data and music can be configured to the helmet in order to track rides and listen to music without obstructing the user's sound field. The ability to group talk with other riders increases the safety of the rider.

Product Benchmark

In order to gain a better understanding the design solution, it is important to benchmark existing products. As the solution consists of a system of hardware working in unison, a pool of existing products was gathered and compared, each sorted into their own categories:

- Vehicles: Examples of existing consumer ready LMV
- Heads Up Display: A variety of HUD products that display information to users
- Safety equipment: Diverse examples of existing safety product

Product Type	Name	Description	Specifications
LMV	XiaoMi Mi Electric Scooter Pro	Electric Scooter	Built in breaking system with brake lights
	Ninebot S-PRO by Segway	Self-Balancing solo vehicle	Follows users, stable, turn signals
	OneWheel XR	Single Wheel all-terrain vehicle	Large wheel provides all-terrain access.
HUD	Google Glass (Enterprise Edition 2)	Industry grade Augmented Reality lenses	Projects content within wearers peripheral vision
	Vuzix Blade	Consumer grade Augmented Reality Lenses	Provides notifications and at-a-glance info
	Microsoft HoloLens 2	All-In-One Augmented Reality headset	Can project digital content in tangible spaces
Safety Gear	Google Jacquard	Jean jacket for commuters	Smart sleeve fabric accepts user input
	Helite TOURING Airbag Jacket	LMV or motorbike jacket	Built in airbags that deploy in case of accident

	CrossHelmet	Smart Helmet	Rear-view camera and ability to accept calls

Table 3 *– Product Benchmarking*

Product Benchmark

Based on the information obtained from the prior benchmark, the existing products can be plotted along an X-Y graph. This will reveal potential product opportunities to be explored as well as provide insight into what current product trends are. The information will be plotted along two axis:

- X: Benefitting the Primary User (Rider) vs Secondary Users (vehicles)
- Y: Active (user input) vs Passive (automated)

Last Mile Vehicles

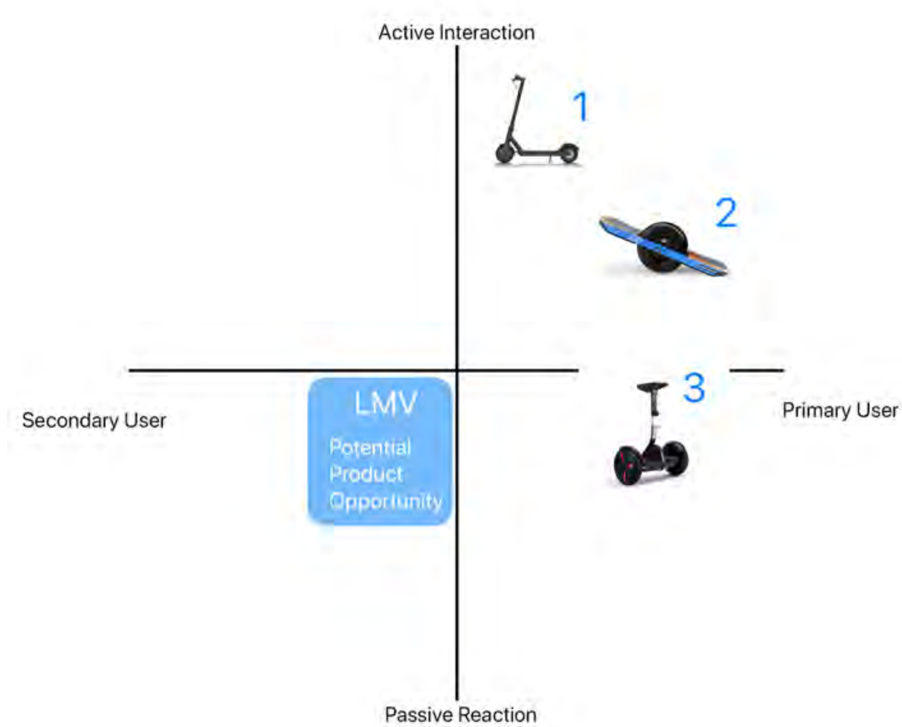


Figure 2-8-1 X-Y Comparison of existing Last Mile Vehicles

4- XiaoMi Mi Electric Scooter Pro - https://www.amazon.com/Xiaomi-Electric-Long-range-Fold-n-Carry-Ultra-Lightweight/dp/B076KKX4BC

5- Ninebot by Segway S-PRO - https://store.segway.com/ninebot-by-segway-s-pro

6- OneWheel XR - https://onewheel.com/products/xr

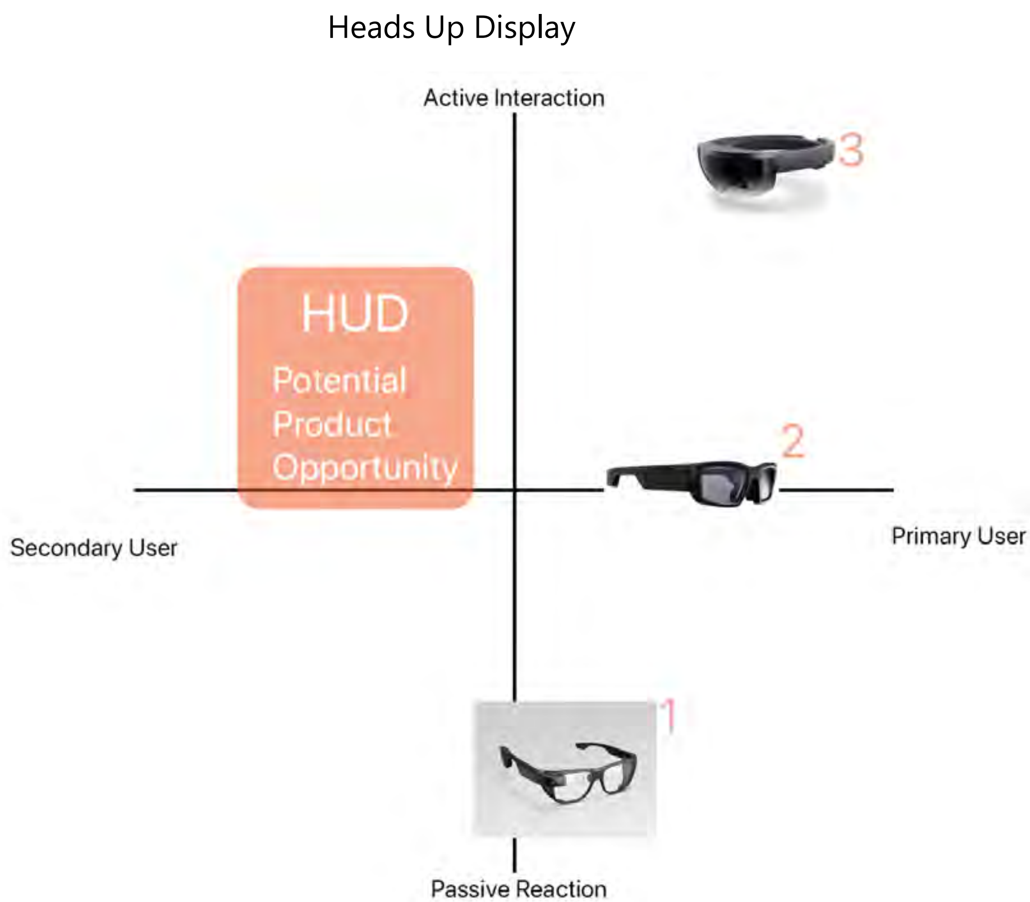


Figure 2-8-2 X-Y Comparison of existing Heads Up Displays

4- Google Glass Enterprise Edition 2 - https://www.google.ca/glass/start/

5- Vuzix Blade - https://www.vuzix.com/products/blade-smart-glasses

6- Microsoft HoloLens 2 - https://www.microsoft.com/en-us/hololens/hardware

Safety Equipment

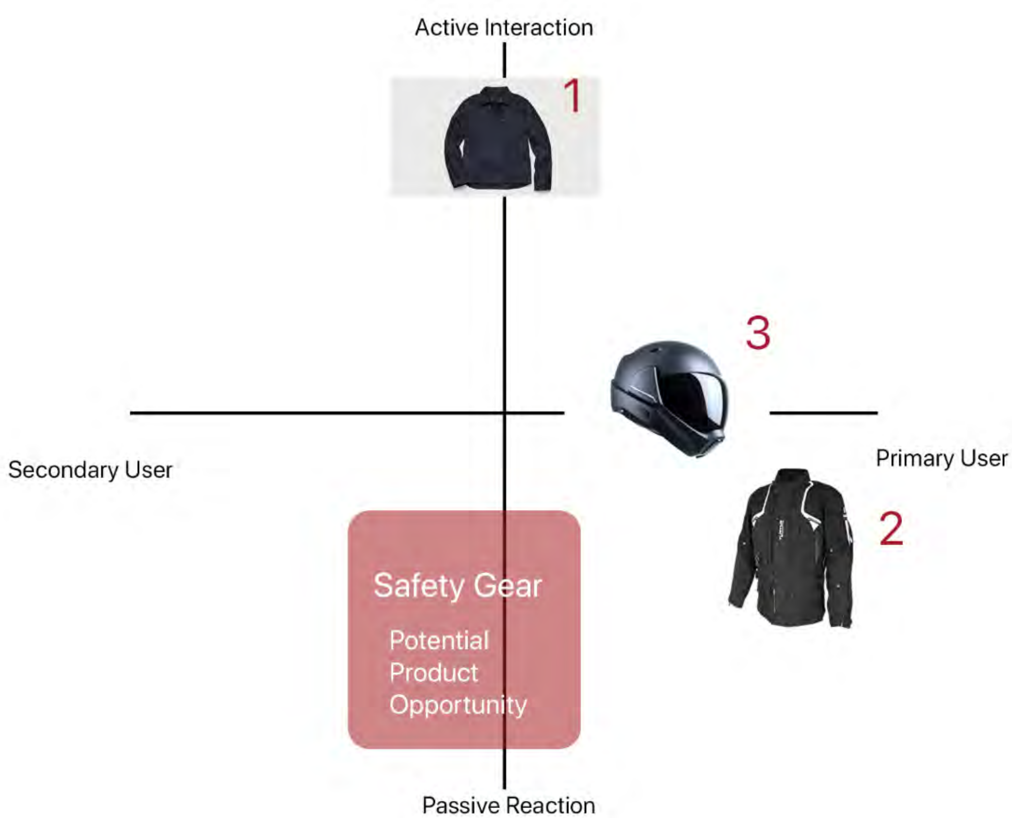


Figure 2-8-3 X-Y Comparison of existing Safety Gear

4- Google Jacquard - https://atap.google.com/jacquard/

5- Helite TOURING Airbag Jacket- https://www.helite.com/touring-grey-adv-rider-jacket-airbag

6- CrossHelmet - https://www.kickstarter.com/projects/491835187/crosshelmet-the-smart-motorcycle-helmet

The products that were chosen to benchmark all have specific benefits and features that could be viable as a thesis solution. Although there are three separate products in this system, there are many attributes that are shared between the three. They will be listed in a table below.

Features	Benefits
Turn signals + Brake Lights	Secondary User Safety
All terrain navigation	User Flexibility
Preventative safety measures	User Safety
Contextual alerts + Notifications	User Experience
Portable	User Comfort

Table 4 – *Features + Benefits for LMV operation*

Benchmarking Functionality

The overall system is built to achieve a single goal; ensuring the safety of the rider. Although three distinct products, they all contain similar aspects that lend themselves to the needs that they satisfy. Although not as fast or as private as a standard automobile, these forms of transportation allow for different benefits over these conventional means. The portability and ease of deployment of these LMV allow them to be more flexible as an urban commuting option; granting users free range to merge between bike paths and the road, allowing them to be used alongside both bikes and cars, and the ability to dismount and roam without the need to find a parking spot.

The following lists focus on the key functions of each product line; Vehicle, Protection, and HUD technology. This information is derived from observations taken during the group ride.

Vehicle findings:

- Although price is factored into the decision of a vehicle brand, prior user experience, reviews, and manufacturing standards sway the purchase power.
- Portability is a must in order to safely and efficiently transport your LMV on and off public transit.
- Being able to alert drivers and pedestrians to your presence is important. Both actively (bell, noise maker), and passively (Turn Signals, Lights).

Protection Findings:

- Current means of protection are not adequate for high speed impacts, collisions, or falls. They are built to protect the most vulnerable parts of the body (Head, Elbows, Knees).
- Current protection is often bulky and cumbersome to wear, having users either hindered by their use, or opt out of using them entirely due to inconvenience and discomfort. Safety gear is often only used for longer rides.
- Smart materials are not yet widely adopted; however, they are used in order to provide input in some use cases. Contextual cues and information can potentially be given by the rider with minimal discomfort.

HUD Findings:

- Heads Up Displays often offload computational power to a remote processing unit. This allows them to be designed to receive + project information; thus, keeping them light and comfortable for the wearer.

- Information is often projected onto a small surface area. This means that the majority of practical and non distracting uses involve key information being displayed off to the side.
- Interaction with the content on the screen can be based on external sensors and machine learning (recognizing objects and displaying appropriate information), or it can be from the user (speaking to a virtual assistant, swiping a touch sensitive pad).

Given this information, decisions that factor into the final design solution can be implemented.

Appendix IV – Needs Analysis

Needs Statement

Last Mile Vehicle safety

Arman Amin

Objective: To generate a needs statement for your product.

To identify main benefits for comparable products.

To relate product benefits with fundamental human needs.

Method: Promotional media (literature/internet) of comparable products are researched and evaluated to determine benefits and design opportunities for your product category.

Product benefits are linked to latent needs (in this case consider fundamental human, and their relative importance to the design of a new product)

Topic: Last Mile Vehicle + Safety equipment

Preliminary Needs Statement

Device to improve the safety of LMV commuters:

- Non-intrusive safety for rider
- Safe alternative transportation

Purpose: Recreation / Competition / **Transportation**

Sections: 1. Initial Needs Assessment

2. Linking Benefits to Fundamental Human Needs

3. Generate a Needs Statement

1. Preliminary Needs Assessment

What the product does

The product provides a safer commute for users who ride LMV (last mile vehicles)

360 initial inquiry

Who are your target market group?	Alternative Vehicle commuters
What does it do?	Transports users within urban areas safely.
Where will it be done?	Outside, primarily to and from public transit + work
When is it done/used/needed?	Rush hour traffic (Morning + Evening)
Why is it needed?	Decrease traffic congestion in urban areas, improve rider safety

Why would someone buy this product?

- Personal safety + security while operating their LMV
- Allows for more seamless transportation in urban areas

2. Linking Benefits to Human Needs

Products with similar benefits were determined, and promotional media for them gathered.

A more in-depth look at the benefits listed in the promotional literature was carried out.

These benefits were related to Human Needs using:

1) Hierarchy of Human Needs (*Maslow*) and
2) Fundamental Human Needs *(Max-Neef)*

Determining Products which Bracket Key Benefits for the Thesis Topic

A key element to a unique and original design is to start with thinking about the user and their needs, rather than current products.

The point of this exercise is not to design a product, but to understand the user and what their key needs are.

Starting design with current products can seriously bias the development of a unique solution.

Thesis Topic

Product or service that promotes safety for LMV riders, commuter vehicles, and pedestrians.

**and other caregivers*

Benefits that bracket topic

1. Non-intrusive safety for rider
2. Safe alternative transportation

Benefit #1: Non-intrusive safety for rider:

- Gloves
- Signals + Lights
- Knee + Elbow pads
- Helmet

Benefit #2: Safe alternative transportation

- Bike (electric or manual)
- Skateboard (electric or manual)
- Scooter (electric or manual)

Based on this, two Tables for **Linking Benefits with Needs** are generated, one for rider safety, and the other for safe alternate transportation.

Benefit #1: Non-intrusive safety for rider

Product that Affords: Smart Helmet

Lumos Kickstart Helmet with MIPS (Multi-directional Impact Protection System) **by *LUMOS***
Price: CDN$ 249.95 & **FREE Shipping**.

Product Description

- Integrated light system
- Rechargeable battery
- Weatherproof
- Safety certified
- Turn signals
- Automatic Warning Lights
- Wireless Remote
- Smartphone App
- Compatible with Apple Watch Health application
- MIPS certified

Specifications

Brand Name	LUMOS
Colour	"Charcoal Black" ("Optional Lime Green" colour)
EAN	865622000315
Material Type	EPS Liner, PC Shell
Model Number	LKHEBKB

Benefits	**Features**
Easily seen on the road	Built in LED system with rechargeable battery
Alerts other commuters to your movement	Turn Signal Lights built in
Able to integrate and monitor ride activity	Connects to Health services through your phone
Alerts other commuters when you're stopping	Hard Break Lights automatically come on

Summary Table: Benefit #1

Product:	Smart Helmet	
Linking Benefit:	***Non-intrusive safety for rider***	
Needs – *long term*	**Needs –** *short term*	**Benefits**
Security	Safety	Provides coverage for rider's head
Esteem	Ergonomic adjustments	One size fits all. Unisex.

Statement of Need *(transport only)*

A security device for LMV riders:

1) Security for the rider
2) Alert for surrounding commuters.

Specific needs to be considered include:

- Safety for the rider
- Ease of use for signal controls
- Ability to keep those around rider aware of presence
- Portability
- Ease of charging

Benefit #2: Safe alternative transportation

Product that Affords: Electric Longboard

Boosted Plus **by** ***BOOSTED***
Price: CDN$ 1,399.99 & **FREE Shipping**.
Product Description

- Integrated light system
- Rechargeable battery
- Weatherproof
- Safety certified
- Turn signals
- Automatic Warning Lights
- Wireless Remote
- Smartphone App
- Compatible with Apple Watch Health application
- MIPS certified

Specifications

Brand Name	BOOSTED
Colour	Orange wheels + Black Grip tape
EAN	859766007231
Material Type	Composite board
Model Number	LKHEBKB

Benefits	**Features**
Flexible Composite Deck	Durable design + More comfortable ride
Able to travel quickly	35 Kph Top Speed
Able to travel far	22.5 Km Range Battery
Can be used traditionally (manual)	Regenerative breaking
Able to use in extreme conditions	Durable and weatherproof
Easy to repair + upgrade components	Additional accessories from manufacturer
Fully in control of speed	Ergonomic Bluetooth controller

https://boostedboards.com/vehicles/longboards/boosted-plus

Summary: Benefit #2

Product:	**Electric Longboard**	
Linking Benefit:	***Safe Alternative Transportation***	
Needs – *long term*	**Needs- *short term***	**Benefits**
Security	Pleasure + Gratification	Sense of speed and control while riding
Social Belonging	Social Expectations Tribal Identity	Users expected to be "different" in terms of preferences Users tend to notice each other, monthly meetups

Statement of Need *(security)*

A portable, convenient mode of transportation that can:

1) Safely allow the rider to commute in Urban Areas
2) Fit within current commuting methods on road

Specific needs to be considered include:

- Portability of product
- Ease of use
- Comfort while using for extended periods of time

Combined Statement of Need for Benefit #1 and #2

Statement of Need *(transport and comfort)*

A system of products that work in tangent with LMV riders to provide an improved sense of security and comfort for the surrounding commuters

Specific needs include:

- ease of use, sense of security and comfort while using
- Ability to travel efficiently and effectively

Fundamental Human Needs

Linking the product benefits with fundamental human needs will utilize two models: Maslow's 'Hierarchy of Human Needs', and 'Fundamental Human Needs' (according to the school of "Human Scale Development" and Manfred Max-Neef).

The 'Fundamental Human Needs' is similar to Maslow's model, but with some important additional categories. For example, in the 'leisure' category, one has 'games, parties'. Games are fun and often highly addictive.

Below is a table summarizing these categories.

Need	Being (qualities)	Having (things)	Doing (actions)	Interacting (settings)
subsistence	physical and mental health	food, shelter, work	feed, clothe, rest, work	living environment, social setting
protection	care, **adaptability**, **autonomy**	social security, health systems, **work**	co-operate, **plan, take care of,** help	social environment, dwelling
affection	respect, sense of humour, generosity, sensuality	friendships, family, relationships with nature	share, take care of, make love, express emotions	privacy, intimate spaces of togetherness
understanding	critical capacity, **curiosity,** intuition	literature, teachers, policies, educational	analyze, study, meditate, investigate,	schools, families, universities, communities,
participation	receptiveness, dedication, sense of humour	responsibilities, duties, work, rights	cooperate, dissent, express opinions	associations, parties, churches, neighborhoods
leisure	imagination, tranquility, **spontaneity**	**games, parties,** peace of mind	day-dream, remember, relax, have fun	landscapes, intimate spaces, places to be alone
creation	**imagination,** boldness, **inventiveness, curiosity**	abilities, skills, work, techniques	**invent, build, design, work, compose,** interpret	spaces for expression, workshops, audiences
identity	sense of belonging, self-esteem, consistency	language, religions, work, customs, values, norms	get to know oneself, grow, commit oneself	places one belongs to, everyday settings
freedom	autonomy, passion, self-esteem, open-mindedness	equal rights	dissent, choose, **run risks,** develop awareness	anywhere

Common benefits and the correlating fundamental human need

Commonly cited product benefits are the following: ***easy, efficient, convenient, comfort***
These are related to **control over one's environment**. Correlating needs are (Max-Neef model):
Protection: **autonomy**, adaptability, work, planning, take care of
Freedom: **autonomy**, self-esteem

Another group of benefits are **experiential,** e.g. ***exciting, stimulating, exhilarating***
These are related to experiences. Correlating needs are (Max-Neef model) are:
Leisure: **spontaneity,** games, have fun, imagination
Freedom: **autonomy**, self-esteem, risk-taking

Beauty and style are important categories not specifically addressed by either the Maslow or Max-Neef models. "Beauty is the quality of being pleasing, especially to look at, or someone or something that gives great pleasure, especially when looking at it." *Wikipedia.* What is pleasing is either innately or culturally derived.

For purposes of this exercise of associating benefits with fundamental human needs, **style and beauty** will be associated with the term **aesthetics** or higher order activities such as **self-fulfillment** and **creativity**.

Benefits and Corresponding Fundamental Human Needs

The fundamental human needs corresponding to the product benefits *(reference Product Research REPORT)* was determined and displayed in the Table below. The relative strength of relationship (strong/moderate/weak) was also indicated.

Table: Benefits and Corresponding Fundamental Human Needs

Safe LMV Operation

	Benefit	*Possible Corresponding Fundamental Human Needs (FHN)*	*Relationship between Benefits and FHN*
1	Comfort	Control, security, self-esteem (mastery)	strong
2	Style	Esteem, belonging, aesthetically pleasing	moderate
3	Efficiency	Accomplishment, autonomy, self-esteem	strong
4	Ease	Accomplishment, autonomy, protection, security, control, self-esteem (mastery)	strong
5	Fun	Leisure (excitement), Participation, Belonging (shared fun)	strong

Comfort in this context is increasing the sensory experience for the rider of being stable, secure, and a functioning part of urban commuting.
Comfort also includes the harshness of the ride (ride harshness would contribute to a feeling of a *loss of control*, increasing possibility of injury (risk), both of which decrease one's sense of protection)

Security is the major fundamental human need met for the rider and surrounding commuters.

Style is an important expression of individuality. What is considered by the group as stylish increases **self-esteem**.

Efficiency is defined as the effort required to perform at a particular level. This is related to **control** the user has during the activity (**autonomy**)

Ease is in many ways related to efficiency in terms for fundamental human needs (i.e. **control, autonomy**).

Fun related to **leisure** ('travel' to new interesting environments) and **belonging** (**shared fun, participation** between multiple LMV riders and other commuters).

Statement of Need

Safe urban transportation using LMVs is based on ease of functioning (transport) (**control, mastery**), and comfort afforded to the rider, pedestrians, and other commuters (**comfort and security**).

LMV transportation is also a **social** activity, since most transport involves interaction and planning with other commuters.
Esteem can be afforded by good styling/quality cues of the device.

Control and **mastery** of the device is related to the performance of the machine (**effectiveness, ease** and **comfort)**.

Appendix V – Sustainability Report

Introduction

The realism of a theorized product solution requires a specific need to include considerations for potential manufacturing and environmental considerations. This increases the ability for this idea to be considered more feasible. These material and manufacturing needs for the potential thesis solution differ based on the peripheral within the family of products. As there are three components to the thesis solution, each product will be discussed separately.

Vehicles

Of all three of the product lines that are being discussed, the LMV is the most complex in terms of design and material usage, having to factor in regulatory decisions that will shape the build of the final vehicle. It faces the challenge of having to be durable enough to ride in the street, yet light enough to carry on to public transit and to store. The components that will be required would be:

- Motor & motor housing
- Tires
- Chassis
- Battery
- Storage bag
- Lighting system
- Computational system

Further research will need to be conducted to gain a better understanding of the materials that will ultimately be used in the final design of the vehicle.

Safety Equipment

Being one of the two wearable components of the system, the product that protects the user from an accident or fall must be light enough to wear without obstructing or inconveniencing the rider. Based on the current direction, components for the safety peripheral will be:

- Padded cushioning on the inside of the product
- A fastening system that will help keep the product aligned
- An airbag system that is deployed when an accident is detected
- The computing system that detects the accident
- Indicator LEDs to alert other riders and drivers of the user’s intents.

Further research and styling will need to go into the design of this component and this section will be updated once a final design direction is chosen.

HUD

Since this is the device that will be the most intimately attached to the user, the HUD needs to be lightweight while also containing an adequate onboard battery to operate at an extended period of time. Major components of the Heads-Up Display include:

- Refractive prism to project light onto lens
- Lens to act as viewfinder for user

- Glass to assist with vision at higher speed
- Input method to control settings (microphone, touch)
- Computational power required to operate
- Cameras and sensors to assist in special awareness
- Projector

These components are dependent on the final design direction.

The following section is included to discuss the sustainable actions that are factored into the environmental importance of LMV operation and how each benchmarked product classification can assist in offering an environmentally sustainable solution.

Seeing as LMV operation is already considered a more environmentally conscious decision, it is safe to say that the equipment that goes along with it must also share the same message. Last Mile Vehicles, much like conventional vehicles, are designed to be repaired as components fail. However, due to the stripped-down nature of these micro mobility options, components are easier to replace and often don’t require input from the original manufacturer (safe for defects in manufacturing or in software). This already poses a large environmentally sustainable opportunity that can be factored into the vehicle design; simple to replace components that require minimal effort to repair.

Where the waste is generated, however, is in the disposable nature of the safety equipment. Helmets and kneepads are designed to sustain a single impact then are rendered ineffective by the damage wrought to them. This wasteful practice, although lifesaving, can impact the environmental consciousness of the design at hand. By implementing a replicable, modular safety system, users do not have to worry about wasting materials should they encounter an accident.

Although indirectly impacting the sustainability of the product system, the HUD, as well as any form of preventative safety measure, can lower the chances of equipment damage, lengthening the life of the products.

Already presented as an environmentally friendly substitute to standard vehicles, the sustainability of the LMV experience is something that is ever-present in the discussion of these alternate modes of transportation. The importance of rider safety and health is paramount to the successful development and deployment of a potential "Last Mile Vehicle" system.

Safety

As the thesis topic revolves around the improvement of LMV operation, safety is the number one priority to the design solution. Risks that are encountered during regular commuting will inherently be presented to the rider. The build of the vehicle will need to fit current standards required for safe navigation in urban areas. Information such as speed, battery percentage, navigation and hazard indication will need to be presented to the user in a non-invasive way in order to continue safe operation. This data can be presented in a subtle and innovative way to the rider. The movement made by the rider must also be telegraphed to surrounding users in order to increase visibility and ease tension between travelers. Materials that are designed to be weatherproof will need to be chosen. Fabrics will need to be easy to clean in order to provide a better user experience.

Health

In the context of this thesis, the 'health' of the user refers to the aspects of commuting that impact the user's wellbeing in the long run. This includes factors that are often overlooked, like the posture of the user, necessary areas needed to be protected during a collision, and factors that impact the user's mood and comfort while operating these vehicles. The benchmarking of existing products shows that there is a lack of a cohesive system that makes the riding experience safer for the operator. The smaller build of the vehicles leads to users dismounting and carrying them on their person. The act of staying mobile and active lends to the healthy nature of LMV.

Environment

Since micro mobility is viewed as an environmentally sustainable and friendly way to commute, the importance of minimizing the environmental impact that the rider will have on the urban landscape. The benefit of working with a smaller footprint means that there are fewer complex components that require potentially environmentally damaging parts. By designing this solution as an all-in-one system of products, the need to build and assemble the goods requires little in the sense of storage post construction, to larger, less environmentally conscious methods of transportation to retail centers or customers' homes.

Product Repairability

Although current LMV are designed to be easily repaired by the user, safety equipment is much more difficult to responsibly manage. Many of the current impact solutions require single use materials that are damaged beyond repair once their need is carried through. This creates a large amount of waste generated and requires the user to spend more in order to replace essential products. By maintaining the modular design that current LMV manufacturers support, identifying and remedying problems becomes easier to do for users and produces less single use waste should the OEM support the reusability of older and damaged components.

Conclusion

As discussed above, there are many considerations that will need to be factored into the overall design of the vehicle.

Appendix VI – Topic Approval Form

Humber Institute of Technology & Advanced Learning
School of Applied Technology
Bachelor of Applied Technology – Industrial Design
Winter 2020
iDSN 4502 Senior Level Thesis Project II
Dennis L. Kappen/Catherine Chong/Sandro Zaccolo

THESIS DESIGN APPROVAL FORM

NAME
Arman Amin

TOPIC TITLE (Brand)
Enhancing the safety and security of Last Mile Commuting in Urban Areas.

PS: Ensure that the visualization of the final design, side views and front views in Illustrator or Photoshop are required to be shown to us for securing an approval

Thesis design is approved to proceed for the following:

✓ **CAD Design Phase**

✓ **Rapid Prototyping and model building phase**

Swx1
COMMENTS: ADD - DETAILING FOR AESTHETICS + STRUCTURAL
→ SUPPORT
→ WORK ON UNIFYING AESTHETICS LINES.
→ FOR RP - ENSURE THAT THE VEST + HUD + LMV ARE
AESTHETICALLY

Signed

Catherine Chong / Dennis L. Kappen