terra

Maglev Streetcar

Industrial Design Thesis Report

Thomas Purchase

How may we revolutionize public transportation in a new city?

by

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Submitted in partial fulfillment of the requirements for the degree of

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Abstract

According to authors of the Proceedings of the National Academy of Sciences, within 50 years, regions of Earth's temperature will rise to uninhabitable levels affecting 30% of the projected human population. This thesis proposes a revolutionary transportation vision for the new megacities these billions of climate migrants may build. The conception of new cities in undeveloped parts of the world, less affected by climate change, creates an opportunity for innovative transportation design not constrained by existing infrastructure. The design will improve user lives in an urban environment by focusing on revolutionary experience change.

Primary research methods include interviews and user observation studies to understand behaviour, accessibility needs, and ergonomic factors. A full-scale ergonomic study will be done to test various elements of human interaction and user comfort. Additionally, existing models can be used to score the system's sustainable factors environmentally, economically, and socially. Research results inform an impactful industrial design solution backed by user-based data.

This thesis report asks how revolutionary public transportation can be designed for new major cities, as a response to climate change migration.

Keywords: transportation, design, micromobility, accessibility, city

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Chapter 1: Introduction

1.1 Problem Definition

Urban transportation is the crucial limiting factor for a local economy. This thesis project aimed to discover the root causes of both human interaction and system-level design flaws in existing solutions to conceptualize a better public transportation solution. Fundamentally, this thesis determines how revolutionary urban transportation can be built in a newly constructed city for the populations of Southeast Asia.

Primary research methods included expert interviews and user observation studies to understand behaviour, accessibility needs, and ergonomic factors. A full-scale ergonomic study tested various elements of human interaction and user comfort. Additionally, existing models can be used to score the system's sustainable factors environmentally, economically, and socially. The research results will inform an impactful industrial design solution with user-based data. This thesis assignment asks how revolutionary public transportation can be designed for new major cities, as a response to economic growth and climate change migration.

1.2 Rationale & Significance

This thesis must determine an effective method and experience of transportation for the population of a proposed megacity. Understanding existing and proposed solutions will be critical to discovering a revolutionary leap in public transportation design. User-based design will support all aspects of this solution. The conception of new cities in undeveloped parts of the world, less affected by climate change, creates an opportunity for innovative transportation design not constrained by existing infrastructure. The design will improve user lives in an urban environment by focusing on revolutionary experience change.

1.3 Background / History / Social Context

The phenomenon of new cities has been observed throughout human history (Shepard, 2019). Due to globalization and industrialism, the world continues to see a massive rise in new city development. Since 1949, over 600 new cities have been built in China alone. This phenomenon is shared across much of Asia and Africa as countries experience massive economic growth and industrialization.

Additional factors leading to mass migration include politics and environmental displacement. According to authors of the Proceedings of the National Academy of Sciences, within 50 years, regions of Earth's temperature will rise to uninhabitable levels affecting 30% of the projected human population (Xu et al., 2020). This thesis proposes a revolutionary transportation vision for the new megacities these billions of climate migrants may build.

Chapter 2: Research

2.1 User Research

This chapter will summarize user and product research. Several methods were utilized to collect data including primary user interviews, user observation, and expert advisor interviews. Additionally, applying secondary research on user demographics and behaviour leads to the creation of complex user personas that inform the vehicle design.

Further product research into both existing and proposed transportation designs created an informed context of comparison for design. This research was done from a global perspective to fully appreciate the nuance of the public transit experience.

2.1.1 User profile - Persona

The nature of this thesis proposes no privately owned vehicles will be operated in the environment of the proposed solution - meaning the population will rely on public transportation. Developing countries in Asia publish limited data about public transit ridership, in particular, rider demographics. The current population of Singapore has been used to model the potential demographics of the “new city” thesis scenario.

A summary of Singapore’s population demographics is shown in the table below. This section provides a further breakdown of each of these categories to create a comprehensive view of the demographics modelled in this component of user research.

Table 1

Singapore Population Demographics (Department of Statistics Singapore, 2022; Glavin, 2017)

Gender	50.9% Female, 49.1% Male
Age	39.4 average
Ethnicity	74.3% Chinese
Income	US$41,592/year
Education (Post-Secondary)	61.8%

Figure 1

Resident Population by Age Group, Singapore, 2015 (Department of Statistics Singapore, 2022)

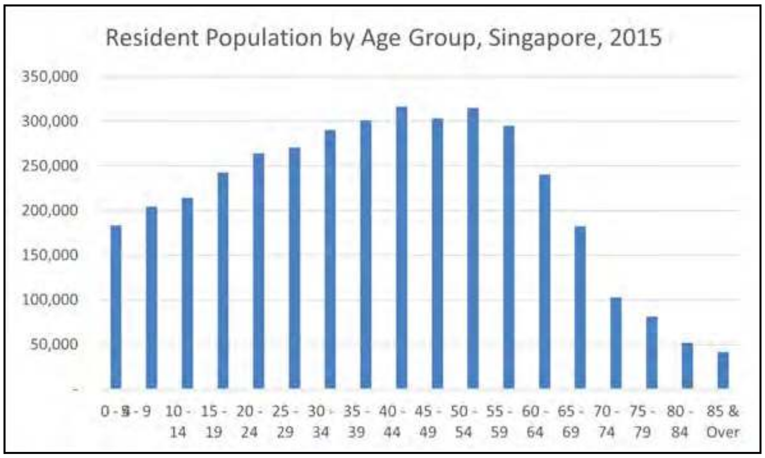
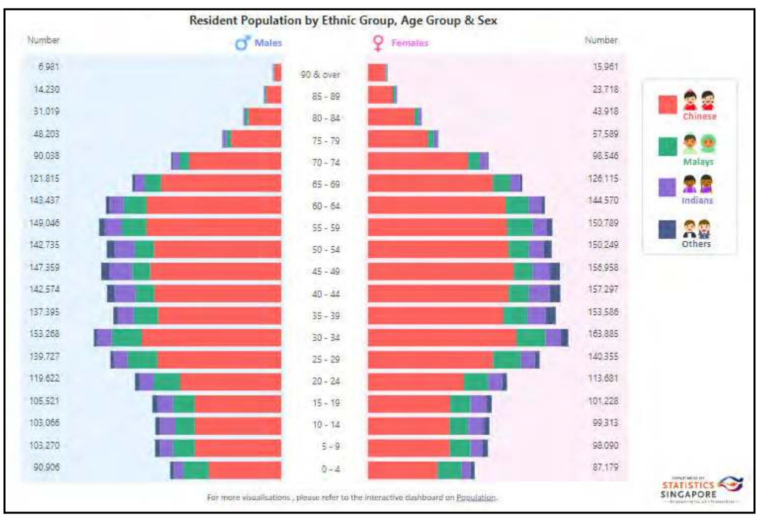


Figure 2

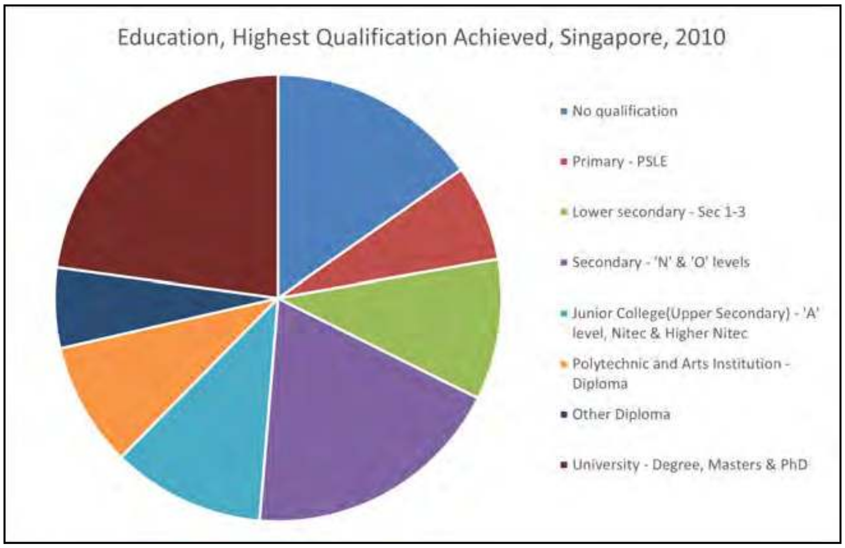
Resident Population by Ethnic Group, Age Group & Sex, Singapore, 2022 (Department of Statistics Singapore, 2022)



The population of Singapore is made up of primarily Chinese, Malaysian, and Indian ethnicities. Ethnicity and nationality can dictate behaviour in a public transportation system, so it is crucial to understand user expectations in reference to culture.

Figure 3

Education, Highest Qualification Achieved, Singapore, 2010 (Glavin, 2017)



Singapore is ranked among the most educated countries in the world, with top performance scores. 61.8% of Singaporeans have achieved a post-secondary education. Culturally, Singapore has a high level of discipline for education.

The economy in Singapore is growing - from 2011 to 2021 the median income has grown by 44% (Lim, 2022). In 2021, the average household income was equivalent to US$41,592/per year. Notably, Singapore is known as a rich country partially due to there being over 270,000 millionaires in 2021 5.4 million population. Meaning about 1 in 20 residents are millionaires in Singapore.

Figure 4

User Persona 1 & 2

Persona 1
Young Professional, Urban Environment

David is a young professional working in Tech. He lives an active social life, and **relies on public transportation** nearly every day. David commutes 25 minutes to work 3-5 times a week, as his job accommodates for hybrid work. His commute to work requires **2 buses and a short walk**. David's job will be moving him to a *New City*, and he hopes the new transportation system will meet his needs.

Friends and family within the city have David travelling 3-7 times a week for social reasons. Often he is **travelling alone** to meet friends, and occasionally he is with a small group. David enjoys how transportation was designed efficiently for his travel, but often he faces **delays**. 3-4 times a week David must order a rideshare to get home at a reasonable time, or make it to a meeting. He also uses a **bike**, but **does not feel safe** during peak hours of traffic in his overcrowded city.

David relies on the city moving fast, and is often frustrated by overcrowding and transportation delays. He is hoping for an improved quality of life in his *New City*, and is excited for his new career opportunity.

David
- 35 years old
- Travels fast and light
- Appreciates green space
- Lives in an apartment
- Works hybrid
- Rides a bike and relies on public transit

Motivations
- Convenience
- Avoiding transportation by car
- Clean air quality and green space

Goals
- Reduce his commute time
- Spend less money on rideshare
- Feel comfortable and safe in his *New City*

Barriers
- Existing transit and city planning
- Overcrowding
- Geographic distance between needs

Likes
- When he has used rail travel
- Hopping right on a bus
- Feeling like he doesn't need a car

Persona 2
Retired Community Member, Urban Environment

Ann is a retired teacher planning to move to the *New City* to stay close to family. Her travel needs include **essential trips** to the grocery store, doctors office, and community centre. Ann has remained social in her retirement and relies on public transit to see her friends and family on a daily basis. Her needs are simple and she prefers **consistency and reliability** when she travels.

Hoping to stay mobile through her old age, Ann stays active. This means frequent trips to her local parks and community centre for fitness. Unfortunately, Ann experiences back and knee **mobility limitations** and occasionally requires a wheelchair. Ann needs a transit solution in the new city that makes her feel dignified when she relies on a wheelchair, and does not segregate her experience from the general population.

Ann loves her **view of the park** from her apartment and takes the train to the far side of the park to go to her fitness class and walk home through the park. She appreciates when she is able to get a **window seat** with a nice view when she rides to the park.

Ann
- 70 years old
- Travels casual
- Lives in an apartment
- Appreciates green space
- Has accessibility needs
- Retired

Motivations
- Friends and family
- Exercise
- Community

Goals
- Live in a cleaner city
- Stay physically healthy
- Feel dignified with her mobility aid

Barriers
- Accessibility, with and without wheelchair
- Overcrowding
- Time spent walking

Likes
- Privacy on the bus
- Clean air quality and green space
- Reliability

This user profile outlines the demographics and behaviour of users in Singapore's existing transportation system. The current reliance on and success of Singapore's transportation system creates a model for the proposed "new city" transportation design. Information was collected using online resources, primarily from the Singapore Department of Statistics. Primary research data is also referenced to create a distinct user persona

Table 2

User Classification

Primary	- Riders - Typical, short-medium distance - Non-Locals - Long distance - Physically impaired
Secondary	- Operations Workers - Vehicle Operators - Maintenence Workers (Cleaning) - Maintenence Workers (Mechanical) - Law Enforcement/Emergency Services
Tertiary	- City Planners - Transportation Systems Managers - Externally Affected Population - Pedestrians - Cyclists

The proposed solution creates an environment where the majority of the proposed city's population becomes a likely user. On average it can be expected that this user will be either a man or woman, aged 40, with a moderate income, and is educated. The dominant ethnic background is Chinese, but due to the geography users will be of diverse cultural and ethnic backgrounds.

Users rely on public transit for the majority of local travel. Ridership in 2021 represents 1.07 trips daily per resident. Travellers in Singapore travel shorter distances and walk less than in comparable cities. Daily travel time is on average 46 minutes a day. This is possible due to a tight-knit city structure with primarily highrise apartments immediately connected to public transit. Users approve of Singapore's transportation at a higher rate than any other city in the world.

2.1.2 Current User Practice

Table 3

Singapore Transit Vehicle Average Daily Ridership by Vehicle (Land Transport Authority, 2023)

Vehicle	Average Daily Ridership 2021 (Thousand Passenger-Trips)
MRT	2100
LRT	151
Bus	3008
Point-To-Point (P2P) Transport (Taxis And Private Hire Cars)	554

Riders in Singapore significantly rely on buses for short-medium distance travel. MRT routes connect most of the city for rapid rail transit. Ridership represents 1.07 trips daily per resident.

Table 4

User Travel Behaviour and Frequency (Moovit, 2022)

Travel Behaviour	Typical Amount
Trip Distance	6.3km
Line Transfers	48% of riders transfer twice, 27% once, 27% do not need to transfer
Daily Time Travelling	46 minutes, 47% spend at least 2 hours a day
Walking Distance Required	0.6km
Time Waiting at Stop	8 minutes

Travellers in Singapore travel shorter distances and walk less than comparable cities (Moovit, 2022). On average, they experience shorter wait times, and only 3% of riders wait over 20 minutes. Daily travel time is on average 46 minutes a day. This is possible due to a tight-knit city structure with highrise apartments connected to public transit.

2.1.3 User Observation – Activity Mapping

Table 5

User Empathy Map

DO?

- Commutes up to 5 days a week
- Works a professional job that relies on him
- Rides a bike to avoid transit
- Visits friends and family in the city using transit
- Uses expensive rideshare services to get places on time
- Enjoys greenspace

30 YEAR OLD MALE
RIDES TRANSIT EVERY DAY

- Lives in an apartment
- Travels fast and light
- Occasionally rides a bike to avoid transit

NEED TO DO?

- Establish a consistent routine for his lifestyle
- Get to work on time without added stress
- Feel safe in his city, especially when on the go
- Safe money on travel

SAY?

- "I can't believe I am going to be late again"
- "No seats?"
- "Is it even safe to get on a bus this crowded?"

SEE?

- People stuck in traffic using cars
- Unsafe conditions on transit regularly
- Constant vehicle delays
- Overcrowding
- Inaccessible conditions for parents and PIW
- Awkward seating/standing arrangements

PAIN

- Being late because of transit
- Overcrowding
- Safety
- Inefficient routes

GAIN

- A smoother system
- More room for riders
- Faster travel times
- More comfortable seating conditions

HEAR?

- People yelling at each other
- Frustrated drivers
- Cars honking
- Chaos

THINK & FEEL

- Can something better be done?
- Do we really need cars downtown?

Table 6

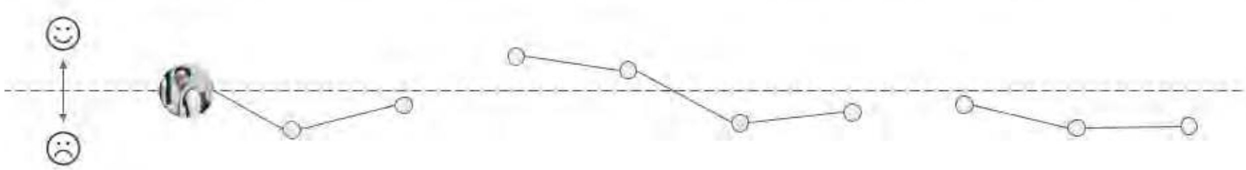
User Journey Map

	Morning			End of Day				Evening		
	Walk to transit	**Ride transit**	**Walk to work**	**Walk to transit**	**Ride transit**	**Stop at grocery store**	**Walk home**	**Meet with friends**	**Go to a restaurant**	**Riding transit home**
User Goals	User desires a calm walk that does not add stress to their routine. Distance to transit stop should be less than 10 minutes	Predictability and minimal crowding Getting a comfortable seat	Travel under 10 minutes to work, stay on time Wants their transit stop to be as close to work as possible	Hoping for as little delay as possible Arrive right before the bus	User hopes to get a seat Wants to feel comfortable on the way home	User wants to get off at a convenient location to briefly walk to the store	User wants a ride home with their bags of groceries	Meet friends at a station and continue as group	Group would like to stay inside a vehicle on their way to a restaurant	User would like a safe, simple ride home
User Actions	Walks to Bus stop Checks ETA and closures Waits for ride	User gets on bus Pays for fare Struggles to find a seat	User requests the vehicle to stop Gets out and walks to work	Leaves work Walks to bus stop Waits for ride	User gets on crowded bus Does not get a seat, barely has standing room	User is able to request stop User cannot make it to exit because of crowding, misses stop	Forced to walk home because of overcrowding Carries heavy bags home	User is constantly checking ETA Trying not to be late Helping lost friend	Delays and closures will force them to miss their reservations Forced to use an expensive rideshare	User waits for transit in the dark Stands in lit area to be safe
User Thoughts	Why is this so unpredictable?	The bus was empty yesterday, am I going to be late?	These cars are so disruptive	Am I going to get a seat today?	I probably should have waited for another bus	Are you serious get out of the way	I'm not even going to try, I hate when this happens	This always happens on my night out	It's raining out can we please not walk, I can't afford a cab right now	I hate this station Am I going to get robbed?
User Feelings	Stress. Frustration, Rush	Rush, Discomfort, Frustration, Crowded	Stress, Crowding, Physical Strain	Relief, Rush, Crowding, impatience	Frustration, Crowding	Anger, crowding, impatience	Exhausted, frustrated	Rush, lost	Stuck, rush, frugal	Unsafe, tired, comfortable
Photos										

Table 7

User Experience Map

	Morning			End of Day				Evening		
	Walk to transit	**Ride transit**	**Walk to work**	**Walk to transit**	**Ride transit**	**Walk to store**	**Walk home**	**Meet with friends**	**Go to a restaurant**	**Riding transit home**
User Goals/ Actions	User desires a calm walk that does not add stress to their routine. Distance to transit stop should be less than 10 minutes	Predictability and minimal crowding Getting a comfortable seat	User travels under 10 minutes to work Wants their transit stop to be as close to work as possible	Hoping for as little delay as possible Able to relax slightly now that their day is over	User hopes to get a seat and arrive at the transit stop right before the bus does	User wants to get off at a convenient location to briefly walk to the store	User wants a ride home with their bags of groceries	Takes different transit route to meet with friends Meets at a station and continues with group	Group would like to stay inside a vehicle on their way to a restaurant	User would like a safe, simple ride home
Problems/ Challenges	Rush hour traffic creates a poor atmosphere for the users walk, cars are honking and breaking laws. User is stressed by these conditions	Outages and delays Overcrowding means no seat, no comfortable standing room	Their job is in between two major stops Rush hour traffic creates chaos and overcrowding	Cars are in a hurry Any delays are cutting into the users evening off	Many others on transit are not commuters Overcrowding on the way home can ruin a good day at work	Transit stops are located in poor locations Overcrowding means the user could not get to the exit in time, missed stop	Forced to walk home because of overcrowding Lack of consideration for people with bags on transit	Unreliable ETAs make it hard to line up arrivals Large stations are hard to find people	Delays and closures will force them to miss their reservations Forced to use an expensive rideshare	User feels unsafe waiting at transit stops in the dark Route changes make it slower to get home at night
Ideas/ Takeaways	Increased transit stops Fewer privately owned vehicles Bike	Higher speed travel with higher TPH	Fewer privately owned vehicles			Build transit stops inside plazas/stores, cars can park close why not transit				Emphasis on safety at night



2.1.4 User Observation - Human Factors of Existing Products

Figure 5

Observation Coding, Features (Watched Walker, 2018)

Figure 6

Observation Coding, User Behaviour (Watched Walker, 2018)

2.1.5 User Observation - Safety and Health of Existing Products

Existing literature were referenced in the development and execution of this study. The primary resource for ergonomic anthropometric data was “The Measure of Man and Woman” (Tilley & Henry Dreyfuss Associates, 2002). Additionally, an ergonomic study on the development of an ergonomic bus seat profile was reviewed to determine contributing factors to a successful seat profile in Asia (Park, et al., 2014). Finally, a comprehensive study containing Japanese anthropomorphic data was used to establish a baseline for American versus East-Asian anthropomorphic data (Yonei, et al., 2008). Together these resources informed the data used in this full-bodied human ergonomic study.

2.2 Product Research

This section will benchmark existing and concept-based products on the market.

2.2.1 Benchmarking - Benefits and Features of Existing Products

Table 8

General Benefits of Existing Products

			
1	2	3	4
TTC Bus	**TTC Streetcar**	**London Underground**	**Singapore MRT**
- Connects suburban parts to the city - Full integration with street traffic - Highly Flexible	- Connects inner city core - Hop on hop off	- Connects Greater London Area - Frequent trains - Express service	- Backbone of urban transportation - Access to stations - Safety

Table 9

General Benefits of Conceptual Products

			
1	2	3	4
Campus Shuttle Wiesmann Design	**GOGO Ride Sharing** Conner Stormer	**Mobuno** XOIO	**Agora E** Ponti Design Studio
- Mobility - Connection - Fuse with its surrounding architecture	- Comfortable - Customizable - Intuitive - Entertainment - No need to own	- Attractive - Mobility - Friendly - All in one	- Social - Zero Emissions - Comfort

Table 10

General Features of Existing Products (Toronto Transit Commission, 2015; TfL Community Team, 2023; SMRT, 2023)

				
	1	2	3	4
	TTC Bus	**TTC Streetcar**	**London Underground**	**Singapore MRT**
Length (ft)	39	91	399	689-1838
Width (ft)	8.5	8	11.5	10.5
Height (ft)	10	12.5	9.5	12
Floor space (ft^2)	331.5	728	4588.5	7235-19299
Volume (ft^3)	3315	9100	43590.75	86814-231588
Seats	33	70	256	150-400
Capacity	51	130	1045	931
Floor space per rider (ft^2)	6.5	5.6	4.4	7.8
Propulsion	Battery-electric	Overhead line	Electric rail	Third rail
Top Speed	110km/h	70km/h	60mp/h	80km/h
Entrances	2	4	28	12-32
Fare System	Cash, member card	Cash, member card	Cash, member card	Cash, member card
Wheelchair Spots	8	2		6-16

Table 11

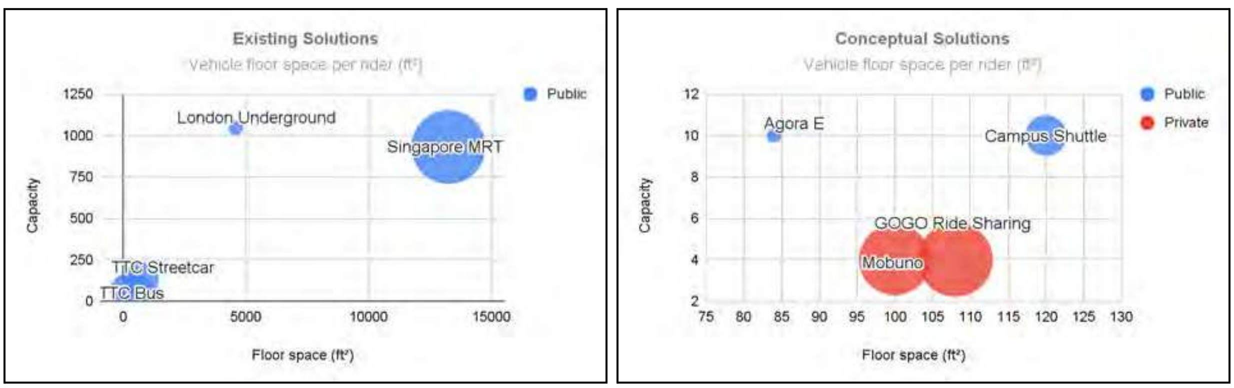
General Features of Conceptual Products (Hemsworth, 2022; Ponti Design Studio, 2022; Stulz, 2021; Wiesmann, 2021)

				
	1	2	3	4
	Campus Shuttle Wiesmann Design	**GOGO Ride Sharing** Conner Stormer	**Mobuno** XOIO	**Agora E** Ponti Design Studio
Length (ft)	15	12	10	12
Width (ft)	8	9	10	7
Height (ft)	9	8	9	8
Floor space (ft²)	120	108	100	84
Volume (ft³)	1080	864	900	672
Seats	4	4	4	8
Capacity	10	4	4	10
Propulsion	Electric, Motor	Electric, Motor	Electric, Motor	Electric, Motor
Top Speed	Low	Highway	Highway	City
Entrances	1	1	1	1
Fare System				
Wheelchair Spots	2	2	0	2

Functionality benchmarking was executed to analyze the primary function of public transportation: transport people. Using public and assumed data the vehicles were compared in a bubble chart (Figure 7) by capacity versus floor space (ft²), with bubbles indicating the floor space per rider (ft²). In future versions, this can be reassessed in a column graph representing capacity and floor space per rider (ft²).

Figure 7

Vehicle Floor Space per Rider of Existing and Conceptual Products (Hemsworth, 2022; Ponti Design Studio, 2022; SMRT, 2023; Stulz, 2021; TfL Community Team, 2023; Toronto Transit Commission, 2015; Wiesmann, 2021)



Existing solutions offer consistent floor space per rider (ft²), expecting riders to occupy a 2-4ft area. Conceptual solutions offer more variable floor space per rider (ft²), with most vehicles offering between 3-5ft² per rider.

2.2.2 Benchmarking - Functionality of Existing Products

Vehicle interfaces of existing and concept products were accessed to determine the user interaction features.

Table 12

Functionality of Existing Products

				
	1	2	3	4
Overall Form	**TTC Bus**	**TTC Streetcar**	**London Underground**	**Singapore MRT**
				
ETA Ticker	X	X	X	X
Map (Digital or Physical)	Physical	Physical, LEDs	Physical	Physical
Touch Display				
Stop Request	X	X		

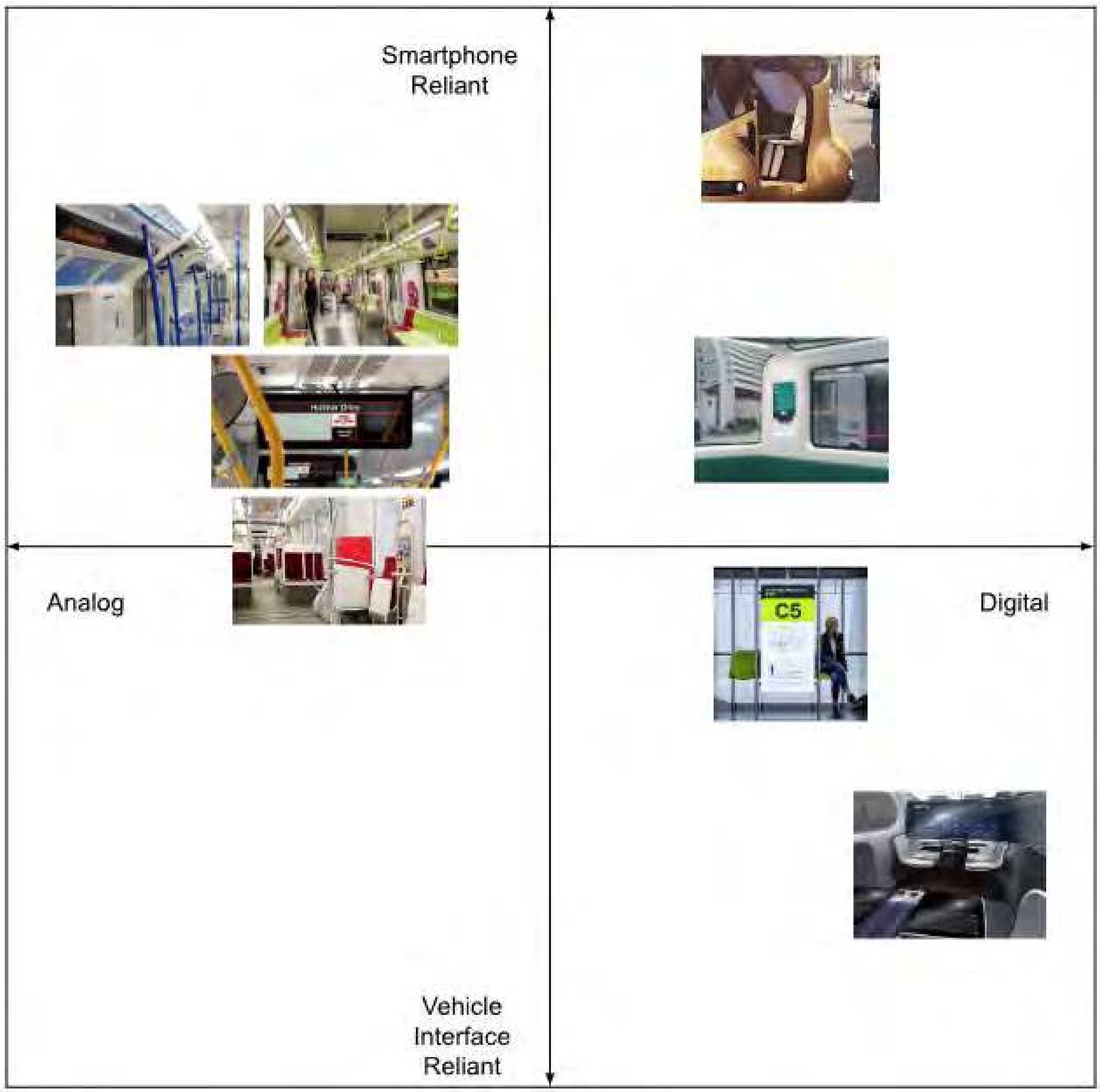
Table 13

Functionality of Conceptual Products

				
	1	2	3	4
	Campus Shuttle Wiesmann Design	**GOGO Ride Sharing** Conner Stormer	**Mobuno** XOIO	**Agora E** Ponti Design Studio
				
ETA Ticker	X			X
Map (Digital or Physical)	Digital	Digital		Digital
Touch Display	X	X		X
Stop Request				

Figure 8

Graph Visualization of Existing and Conceptual Product Interface Qualities



Existing vehicles are primarily analog, not relying on passenger technology or interactive screens. Conceptual solutions rely heavily on digital interfaces, and some require smartphones to function at all.

2.2.3 Benchmarking - Aesthetics and Semantic Profile of Existing Products

Table 15

Aesthetics and Semantic Profile of Existing Products

				
	1	2	3	4
Overall Form	**TTC Bus**	**TTC Streetcar**	**London Underground**	**Singapore MRT**
Shape	Rectilinear	Rectilinear (rounded)	Rectilinear (rounded)	Rectilinear (rounded)
Symmetry	Left/Right	Left/Right, Front/Back	Left/Right, Front/Back	Left/Right, Front/Back
Exterior Colour	White, Red, Black, Yellow	White, Red, Black, Yellow	White, Red, Black, Blue	White, Red, Black
Graphic Style	Linear	Organic	Geometric	Linear

Table 16

Aesthetics and Semantic Profile of Conceptual Products

				
	1	2	3	4
	Campus Shuttle Wiesmann Design	**GOGO Ride Sharing** Conner Stormer	**Mobuno** XOIO	**Agora E** Ponti Design Studio
Shape	Rectilinear	Rectilinear (rounded)	Rectilinear (rounded)	Rectilinear
Symmetry	Left/Right, Front/Back	Left/Right, Front/Back	Left/Right, Front/Back	Front/Back
Exterior Colour	Black, Grey, Green	White, Grey, Blue	Accent colourway, Black	White, Black, Red
Graphic Style	Rectilinear	Geometric	Organic	Rectilinear

Figure 9

Graph Visualization of Existing and Conceptual Product Design Qualities

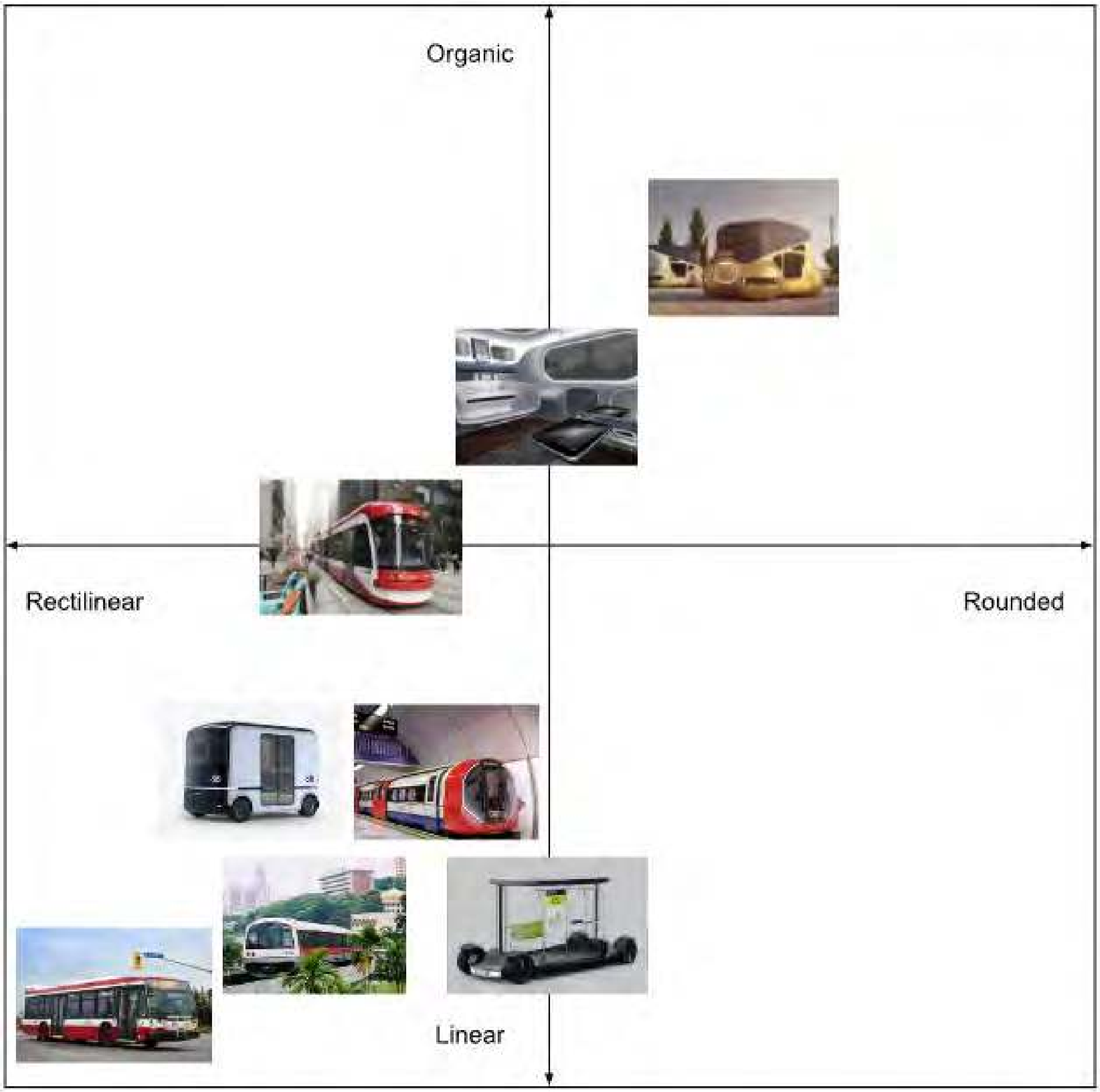


Table 17

Design Comparison Takeaways

Shape	- All vehicles are rectilinear in nature, and modern design trends observed are rounded
Symmetry	- All vehicles are primarily symmetrical, asymmetry comes from the direction of drive and door locations
Exterior Colour	- Most concepts rely on black and white with accent colours
Graphic Style	- Almost all concepts rely on linear graphics

2.2.5 Benchmarking - Sustainability of Existing Products

Existing sustainable efforts globally are often limited by systemic design, and it is a primary goal of this project to address those large-scale issues with innovative solutions (Jacobs, 1961). The conceptual system design of this thesis relies on two existing sustainability initiatives - magnetic levitation (maglev) train propulsion, and driverless cities.

Maglev technology uses electromagnetic forces to both lift (repel) the vehicle above the ground and propel it forward (Macola, 2020; Northeast Maglev, 2020). This technology creates many environmental advantages including a potential complete reliance on clean energy, elimination of air emissions, and zero vehicle particulate pollution. Additionally, maglev trains are near silent at speeds under 200km/h and have zero vibration effect on the ground below (Retzmann et al., 2012). Overall, this thesis proposes it may be the ideal technology for mass urban transportation in relation to the environment and surrounding quality of life.

Through primary and secondary research, it was determined the foundation of this thesis design was going to address privately owned vehicle congestion (traffic) by eliminating the use of privately owned vehicles in the proposed system. Traffic is an inherent flaw in urban environments, described by Jane Jacobs (1961) as the “attrition of automobiles”. The approach to the proposed urban design system relies on cities being designed for people, and not for cars. Reallocating car infrastructure (roads, parking lots, highways) allows for an optimal infrastructure based upon a balance of public transportation and micro-mobility. This approach brings systemic change leading to massive environmental and travel efficiency gains.

2.3 Summary of Chapter 2

Through extensive user and product research an informed approach to addressing experience-level design is formed. Overlapping research and development phases contributed to creative ideas that become enriched through discovered information.

Chapter 3 - Analysis

3.1 Analysis

3.1.3 Categorization of Needs

Table 18

User Needs

Immediate Needs	Latent Needs	Wants/Wishes
Safety - Threat to safety from vehicles, individuals, isolated environments (bus stops) - Vehicle safety is an assumed risk, users may not consider that a fully automated system will have minimal vehicular accidents	Car-free Roads - Privately owned vehicles demand physical space that big cities can not effectively accommodate - Eliminating cars in city centers creates opportunity for truly efficient public transit	Efficiency - Users want more immediately available vehicles when they arrive at a store - More trains per hour (TPH) and higher speeds - Faster door-to-door times
Comfort - The user may not be aware that more comfortable and ergonomic considerations can be made - Seating option variety	In-Seat Digital Interaction - When offered physical space and privacy: opportunity to do more while seated arrises - AR and other emerging interactive technologies can be integrated into the seating space	Privacy - Users want more personal space, or more perceived personal space - Privacy can be designed in a compact yet effective way

3.2 Analysis - Usability

The user experience of existing vehicles can be summarized by its effectiveness ergonomically, convenience, efficiency, and impact on user daily life. User journey maps and experience maps are used to qualify the existing commuter experience in a typical city.

3.2.1 Journey Mapping

Table 6, Review

User Journey Map

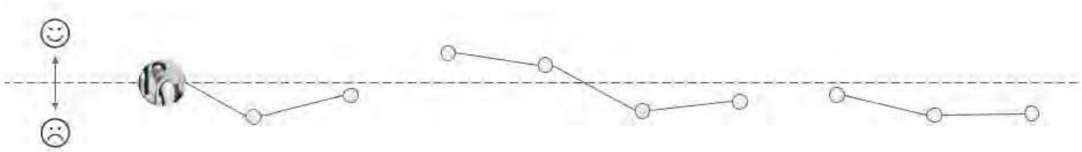
	Morning			End of Day				Evening		
	Walk to transit	Ride transit	Walk to work	Walk to transit	Ride transit	Stop at grocery store	Walk home	Meet with friends	Go to a restaurant	Riding transit home
User Goals	User desires a calm walk that does not add stress to their routine. Distance to transit stop should be less than 10 minutes	Predictability and minimal crowding Getting a comfortable seat	Travel under 10 minutes to work, stay on time Wants their transit stop to be as close to work as possible	Hoping for as little delay as possible Arrive right before the bus	User hopes to get a seat Wants to feel comfortable on the way home	User wants to get off at a convenient location to briefly walk to the store	User wants a ride home with their bags of groceries	Meet friends at a station and continue as group	Group would like to stay inside a vehicle on their way to a restaurant	User would like a safe, simple ride home
User Actions	Walks to Bus stop Checks ETA and closures Waits for ride	User gets on bus Pays for fare Struggles to find a seat	User requests the vehicle to stop Gets out and walks to work	Leaves work Walks to bus stop Waits for ride	User gets on crowded bus Does not get a seat, barely has standing room	User is able to request stop User cannot make it to exit because of crowding, misses stop	Forced to walk home because of overcrowding Carries heavy bags home	User is constantly checking ETA Trying not to be late Helping lost friend	Delays and closures will force them to miss their reservations Forced to use an expensive rideshare	User waits for transit in the dark Stands in lit area to be safe
User Thoughts	Why is this so unpredictable?	The bus was empty yesterday, am I going to be late?	These cars are so disruptive	Am I going to get a seat today?	I probably should have waited for another bus	Are you serious get out of the way	I'm not even going to try, I hate when this happens	This always happens on my night out	It's raining out can we please not walk, I can't afford a cab right now	I hate this station Am I going to get robbed?
User Feelings	Stress, Frustration, Rush	Rush, Discomfort, Frustration, Crowded	Stress, Crowding, Physical Strain	Relief, Rush, Crowding, impatience	Frustration, Crowding	Anger, crowding, impatience	Exhausted, frustrated	Rush, lost	Stuck, rush, frugal	Unsafe, tired, comfortable
Photos										

3.2.2 User Experience

Table 7, Review

User Experience Map

	Morning			End of Day				Evening		
	Walk to transit	Ride transit	Walk to work	Walk to transit	Ride transit	Walk to store	Walk home	Meet with friends	Go to a restaurant	Riding transit home
User Goals/ Actions	User desires a calm walk that does not add stress to their routine. Distance to transit stop should be less than 10 minutes	Predictability and minimal crowding Getting a comfortable seat	User travels under 10 minutes to work Wants their transit stop to be as close to work as possible	Hoping for as little delay as possible Able to relax slightly now that their day is over	User hopes to get a seat and arrive at the transit stop right before the bus does	User wants to get off at a convenient location to briefly walk to the store	User wants a ride home with their bags of groceries	Takes different transit route to meet with friends Meets at a station and continues with group	Group would like to stay inside a vehicle on their way to a restaurant	User would like a safe, simple ride home
Problems/ Challenges	Rush hour traffic creates a poor atmosphere for the users walk, cars are honking and breaking laws. User is stressed by these conditions	Outages and delays Overcrowding means no seat, no comfortable standing room	Their job is in between two major stops Rush hour traffic creates chaos and overcrowding	Cars are in a hurry Any delays are cutting into the users evening off	Many others on transit are not commuters Overcrowding on the way home can ruin a good day at work	Transit stops are located in poor locations Overcrowding means the user could not get to the exit in time, missed stop	Forced to walk home because of overcrowding Lack of consideration for people with bags on transit	Unreliable ETAs make it hard to line up arrivals Large stations are hard to find people	Delays and closures will force them to miss their reservations Forced to use an expensive rideshare	User feels unsafe waiting at transit stops in the dark Route changes make it slower to get home at night
Ideas/ Takeaways	Increased transit stops Fewer privately owned vehicles Bike	Higher speed travel with higher TPH	Fewer privately owned vehicles			Build transit stops inside plazas/stores, cars can park close why not transit				Emphasis on safety at night



3.3 Analysis - Human Factors

Understanding the required full-bodied human interaction design (FBHID) of a transit vehicle was done using digital and physical ergonomic testing. Design schematics referencing Tilley & Henry Dreyfuss Associates (2002), Park, et al. (2014), and Yonei, et al. (2008) all contributed to the dimensions referenced in a 1:1 ergonomic buck study. Human subjects were used in the study to provide diverse feedback on the design configuration. Additionally, virtual reality (VR) environments were created to contribute to a full-scale understanding of the interior experience of the vehicle. This section covers the methods and results of the various human factors study, leading to an informed design diagram.

3.3.1 Product Schematic - Configuration Diagram

The following ergonomic diagrams were created for and refined by the various 1:1 ergonomic studies:

Figure 10

Vehicle Schematic and Floor Plan

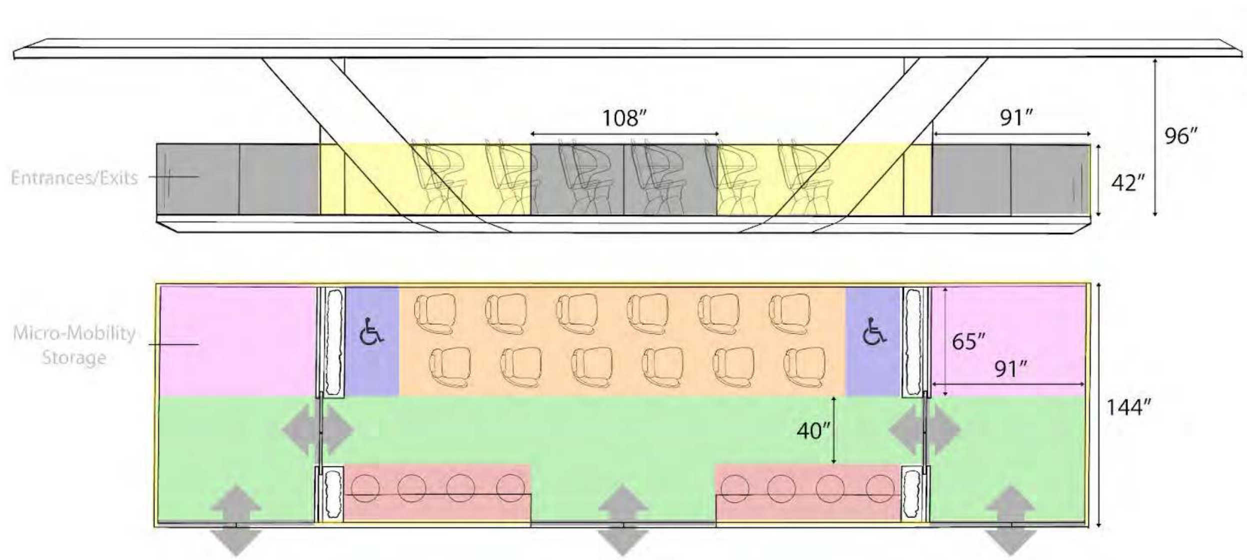


Figure 11

Vehicle Schematic and Floor Plan, Alternate Bench Seating Design

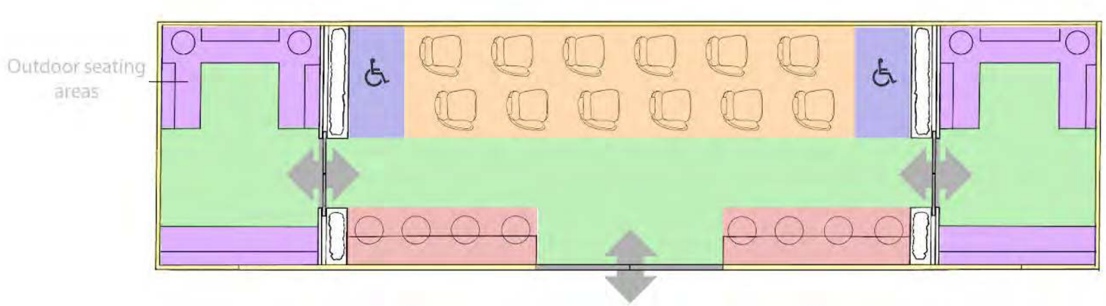


Figure 12

Primary Seat Dimensions

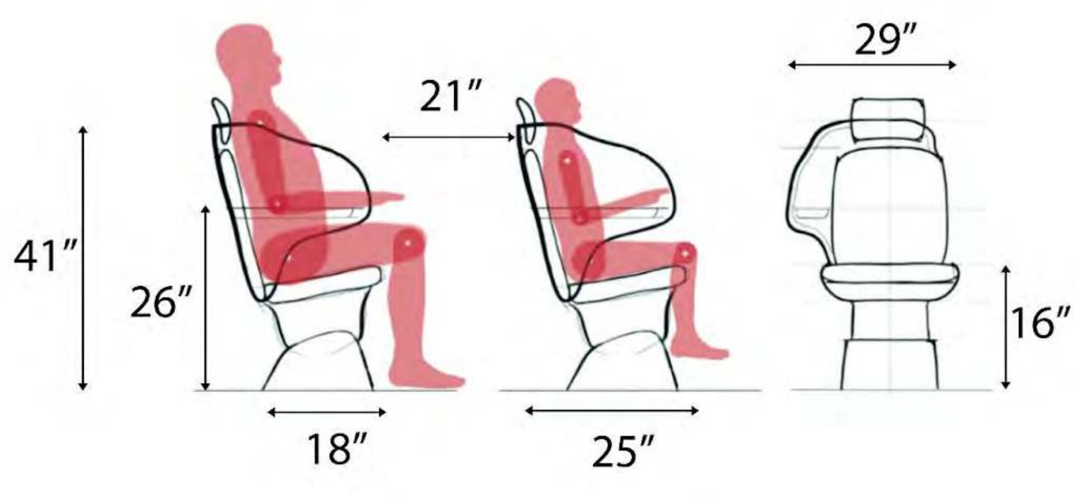


Figure 13

Primary Seat Arrangement and Visibility

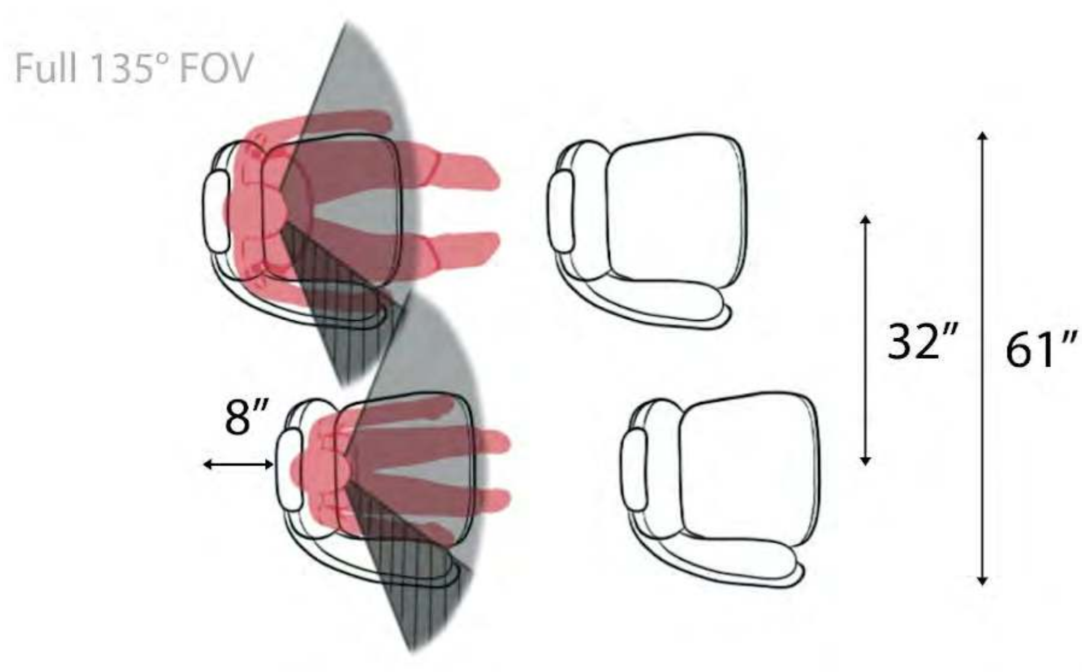
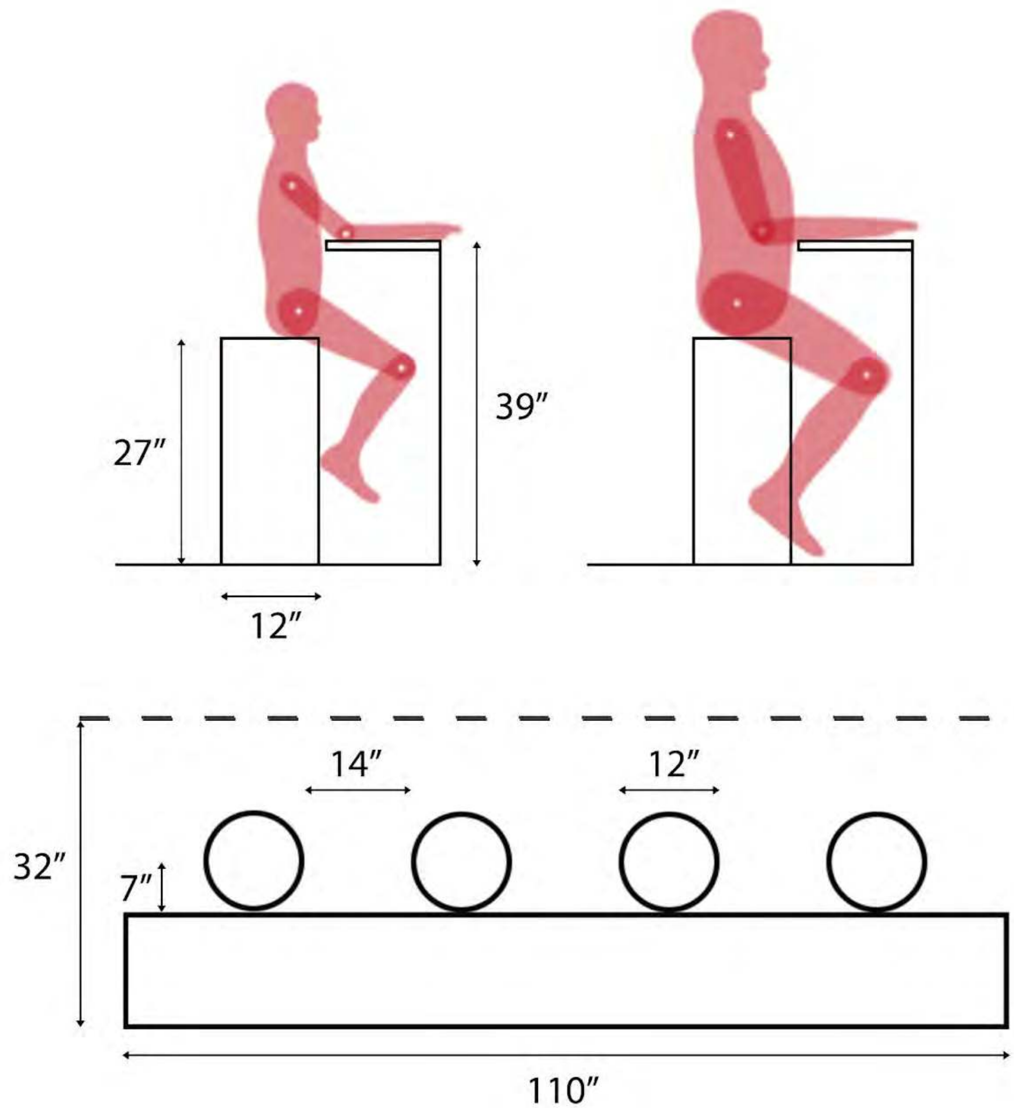


Figure 14

Counter and Counter Stool Ergonomic Dimensions



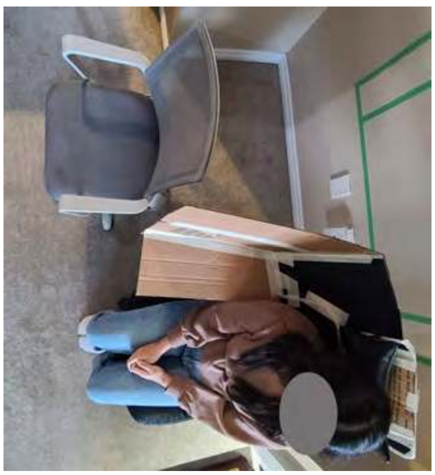
3.3.2 Ergonomic - 1:1 Human Scale Study

A 1:1 ergonomic buck was created to test the interaction and ergonomic constraints as outlined in the various ergonomic schematics. The model was created using cardboard, foam core board, tape, polystyrene foam sheets, and existing furniture (both adjustable and static). The model was tested by the 50th and 65th percentile male and 60th percentile female. The following table details the user study of the ergonomic buck with component images, positive result details, and negative result details:

Table 19

1:1 Ergonomic Buck Study, 50th percentile Female and 65th percentile Male

Component	Positive Result	Negative Result
Primary Seat *This study aimed to verify the dimensions, ergonomics, visibility, proximity, privacy, interaction, and ingress/egress of the primary seat.*		
 **Seated, Ergonomics**	- Seat height (16”) - Seat width (20”) - Headrest adjustability	- Seat pan (18”) - Armrest height (8”) - Armrest proximity to elbow, can’t rest arm at side, must use armrest

 **Seated, Privacy**	- Users felt privacy but maintained awareness of their surroundings - Users did not have a direct view of each other's smartphones while in use - User can see the heads and legs of other passengers but not their torso or arms	-Users view of the window was slightly obstructed by the corner of barrier
 **Seated, Visibility**	- User has full visibility of the window from both seats - User has an unobstructed view of the exit doorway	- User does not have an armrest on the left side
 **Seated, Interaction**	- Fully visible screen distance and size potential - Physical room for hand gestures - Physical room for control near armrest	- Not reachable by touch without standing

 **Ingress/Egress**	- Room while sitting, in front and besides - Ingress/egress pathway accommodates the user with a small bag easily	- Initially too much space, dimension reduced (32” to 21”)
Counter and Counter Stool *This study aimed to verify the dimensions, ergonomics, proximity, and ingress/egress of the counter and counter stool.*		
 **Seated, Ergonomics**	- Distance between thigh and bottom of surface (6”) - Depth of counter (14”) - Stool height to counter height distance (12”) - Foot rest feature - Ingress/egress space - Proximity to other seated passengers (26” OC) - Stool distance from the counter edge (7” OC)	- Stool height (27”) - Stool height to counter height distance, suggested lower 1” (12”) - Footrest heights from seat (10.5” and 19”)

 **Counter Height, Standing**	- Counter height (39”) - Depth of counter (14”) - Foot space (14”)	- Stool proximity makes this posture less-likely (14”)
 **Counter Height, Leaning**	- Elbow resting height (39”)	- Stool proximity makes this posture less-likely (14”)

Perimeter Railing *This study aimed to verify the dimensions and ergonomics of the perimeter railing.*		
 **Railing Height, Leaning**	- Elbow resting height (42”)	- Perceived strength of glass - No railing to hold
Navigation Interface *This study aimed to verify the dimensions, ergonomics, visibility, usability, and interaction of the navigation interface.*		
 **Touch Interface, Center**	- Distance between user and wall (27” to ankle)	- Interface size 2 (42”) is excessive and will not be considered for the remainder of this study

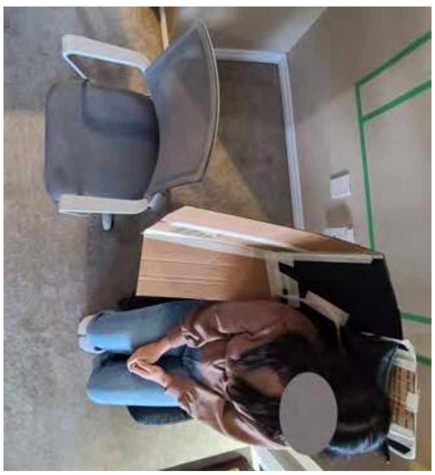
 **Touch Interface, Top**	- Reachability - Top height from floor (74”) - Preferred high point (8” from top)	- Mild back flexion
 **Touch Interface, Side**	- Reachability - Interface width (30”)	- Interface size 2 width (42”)

 **Touch Interface, Bottom**	- Reachability - Bottom height from floor (24") - Preferred low point (10" from bottom)	- Moderate back flexion
Bench Seating *This study aimed to verify the dimensions, ergonomics, visibility, and proximity of the bench seat.*		
 **Bench Seat, Ergonomics**	- Perimeter railing height (42") - Proximity to other seated riders (20" OC) - Seat pan (18") - Back height (31")	- Seat height, suggested lower 1-2" (18")

Table 20

Detailed Analysis for each of the Ergonomic Buck Components in a Summary of Results

<table>
<tr><th>Component</th><th>Analysis</th></tr>
<tr><td colspan="2">Primary Seat
The primary seat was overall successful dimensionally, ergonomically, and functionally. Many dimensions undetermined by referenced data were determined as the model was constructed to accommodate the 50th percentile user.</td></tr>
<tr><td>
Seated, Ergonomics</td><td>Ergonomically, the users felt the seat was sufficiently comfortable in most considerations. Multiple dimensions were considered too large by the 50th percentile female user: seat pan, armrest height, and armrest width near the elbow. These dimensions can all be modified within the suitable range for all three users.
As shown in the ergonomic schematic, it is dimensionally challenging to create a comfortable chair for up to the 99 percentile. Due to the user demographics (primarily, South-East Asian), user results favouring smaller dimensions will be implemented to accommodate a statistically shorter population (Yonei, et al., 2008).
Ideas to add to the feature set included an elevated footrest to encourage users to lean back into the backrest. Chair tilt may be incorporated to further encourage a more relaxed posture in the primary seat.
Users had concerns about the inability to rest their arm in between the armrest. This can be resolved by reducing the dimensional width of the armrest by 2-4”, or removing a section of the armrest nearest to the elbow. Overall, the dimensional width of the armrest was positively received by all users.</td></tr>
<tr><td></td><td>The privacy barrier component of the primary seat was considered overwhelmingly positive by the users. Users maintained both a sense of privacy and awareness due to the dimensional balance of the barrier. It was determined through this study that users feel sufficiently private when their torso, lap, arms, and hands are not fully visible to other riders. Users preferred to be able to see over the barrier to maintain awareness of their surroundings. Users could see the majority of other riders'</td></tr>
</table>

Seated, Privacy	heads, and the offset angle of the seating arrangement prevented consistent awkward interactions between riders. The offset dimension between the aisle and window seat was determined by the window seat users' ability to view the aisle seat user's cell phone while in use in their lap. This dimension was significantly reduced from the assumed 17" to just 8". This contributes to the overall impression of privacy between riders. Users suggested frosted glass as a barrier material to reduce the cluttered appearance of the seat array and allow some light to filter through. This may impact the impression of privacy.
 **Seated, Visibility**	Visibility in the primary seat was tweaked to fully accommodate the 50th percentile user, while balancing the opposing percentile requirements. Functionally, this meant all users had a full view capability over the barrier while covering the majority of their torso. As seen in the ergonomic schematic, larger users, particularly those who are overweight, may experience less torso privacy from riders in the aisle. Per the design, all users should feel sufficient privacy from adjacent riders. By design, both aisle and window seat riders have a minimally obstructed view out the vehicle window. In the study, all users were satisfied with their ability to see out the window. Due to the simplicity of the ergonomic buck's geometry, some users reported a slightly obstructed view from the aisle seat by the corner of the window seat's barrier. This has been addressed by more flowing geometry including rounded edges. Users reported a suitable ability to view the doorway of the vehicle and potential arrival screens along the top of any walls.
	User study was done to determine the physical potential for digital interactive interfaces on the back of the primary seat. Dimensionally there is sufficient opportunity to integrate a large screen on the back of the chairs. The viewing angle is not currently acceptable because the back of the chair tilts down. Accommodating this is possible but may reduce legroom during ingress and egress. Interface controls were undetermined at the time of testing. Users have sufficient dimension for hand gestures, personal device tethering, and armrest controls.

Seated, Interaction	A dimensional opportunity is available to design for hand gesture control, including augmented reality interfaces. This could allow users to avoid unsanitary touch points of shared devices and reduce the bulk of any physical screens. This sort of technology integration would benefit from the featured privacy barrier.
 **Ingress/Egress**	Entering and exiting the primary seat arrangement required a balance of many dimensions. All assumed dimensions were able to be significantly reduced allowing for increased accessibility space at the front and back of the primary seat arrangement. The users were satisfied with the resulting compact dimensions. Larger users will need to side-step during ingress and egress, but while seated there is comfortable legroom and potential for personal belonging hangers on the back of the seats. Other seated users felt mildly disturbed by the primary users' ingress and egress. This was a reasonable disturbance and was balanced while determining compact dimensions. Users consistently placed a hand on the top edge of other seats during both ingress and egress. This may indicate a requirement for weight-bearing handles to contribute to affordance during this process. A light indication may be incorporated into the seats to show vacancy to users entering the vehicle looking for a seat.

Counter and Counter Stool *The counter and counter stool study determined the approach to stool height (and counter relative counter height) needs to be reassessed to more effectively address hop-on hop-off behaviour.*	
 **Seated, Ergonomics**	Users were generally satisfied with the stool-to-counter relationship. The primary concern among users was the overall height barrier to get on top of the stool. The height of the stool required all users up to the 65th percentile male to lift themselves onto the seat in an uncomfortable manner. This will be addressed with overall reduced dimensions to the stool and counter while considering a standing posture. Adjustability was considered, however, it presents complexity in the counter-to-stool height relationship. Due to the height of the stool, footrest use was required by all users. The existing furniture footrests were incorrectly proportioned for all users due to the increased seat height. This will be addressed as the overall stool height is determined.
 **Counter Height, Standing**	Counter height while standing was resoundingly successful among users. The proximity of stools does not eliminate this posture, but it does restrict larger users and will be less likely while adjacent stools are occupied. Regardless, this posture successfully contributes to the hop-on hop-off desirable behaviour.

 **Counter Height, Leaning**	Counter height while leaning was resoundingly successful among users. The proximity of stools does not eliminate this posture, but it does restrict larger users and will be less likely while adjacent stools are occupied. Regardless, this posture successfully contributes to the hop-on hop-off desirable behaviour.
Perimeter Railing *The perimeter railing test was largely successful and will act as a starting place for future refinement and development in a more elaborate design.*	
 **Railing Height, Leaning**	The perimeter railing of the vehicle allows for an open-air passenger experience while maintaining safety. Commercial railing is bound to a mandatory minimum of 42” (Wagner Contributors, 2020). This dimension was suitable for all users. The dimension may be increased to contribute to perceived safety while travelling at high speeds. Additionally, perimeter railing walls may be designed to extend and enclose the vehicle during undesirable weather events.

Navigation Interface *This study allowed for a user-based foundation to design innovative digital interface solutions to aid riders with navigation.*	
 **Touch Interface, Center**	The navigation interface study aimed to prove the dimensional limits of a wall or pedestal-mounted navigation assistance display. Two-dimensional variations of this interface were created to determine a suitable size: 1. Interface size 1, 50” x 30” 2. Interface size 2, 50” x 42” Interface size 2 was deemed excessive in size and was not considered beyond this component of the study. Users are able to comfortably stand at an appropriate distance within their reach. The study determined a comfortable range within the screen for interactive buttons. Visual material can comfortably occupy the entire dimension of interface size 1.
 **Touch Interface, Top**	The top of the screen is moderately reachable for the 60th percentile female. The user preferred interactive buttons to be below 8” from the top of the screen to avoid flexion and neck strain. However, 1st percentile users may struggle to reach these heights. This can be accommodated with sensors to raise and lower the information along the large screen. This will also benefit users who rely on wheelchair support.

<table>
<tr><td>
Touch Interface, Side</td><td>The sides of the interface are sufficiently within reach for all users. This study confirmed interface size 2 to be excessive.</td></tr>
<tr><td>
Touch Interface, Bottom</td><td>All users involved in the study could comfortably reach the bottom of the screen with moderate back flexion. The 60th percentile female preferred to not reach below 10” from the bottom of the screen. As previously mentioned, this can be addressed with adaptable on-screen button heights.</td></tr>
</table>

Bench Seating *This study tested and proved bench seating ergonomics to create alternate directions for the porch environment of the proposed thesis design.*	
 **Bench Seat, Ergonomics**	The bench seat study was intended to confirm dimensions in the event that this direction is included in the design. This is a design option and is not currently the primary solution. Dimensionally and ergonomically this study was successful. Users recommended lowering the seat height by 1-2” to contribute to a bench/couch experience.

The complexity and scope of a large-scale passenger vehicle created limitations for this study. Understanding the full environmental balance of the vehicle interior was not a part of this study. This experience will be tested and proven using virtual reality and a full-scale 3D digital mock-up of the vehicle. The main consideration areas identified by this study include:

1. Counter stool height
2. Primary seat weight-bearing handles
3. Elbow-armrest interference

This study did not yet address the ergonomics of micro-mobility storage and overcrowding. A secondary ergonomic study may have to be conducted to establish guidelines for the featured micro-mobility vehicle storage. If implemented, this will be a critical system that evolves from the typical front-of-bus bike storage rack. The future of micro-mobility trends may need to be considered when designing this solution.

Overcrowding is a practical problem that the proposed solution does not yet fully address. Further ergonomic considerations will need to be made for the vehicle while its seats are full. Commonly, vertical and horizontal metal bars are used in combination with various handles to allow for close proximity rider standing space. Overcrowding is a primary factor driving the need for revolutionary vehicle design, and it is a goal of this thesis project to address it.

Based on learned and ideated experiences during this study, a number of alternate possibilities arose. Those alternate possibilities are as follows:

1. Outdoor patio (bench/couch) seating at the front and rear of the vehicle.
    - This may eliminate effective micro-mobility storage in that area
    - It may also interfere with the proposed entrances
    - It will contribute to the seats-to-square footage ratio
2. Various adjustments to the primary seating arrangement to accommodate more wheelchair and stroller locations
3. Overall floor plan direction alternatives using established component designs

This study aided the determination of ergonomic and dimensional constraints within the proposed vehicle. Significant refinement to the compactness of the overall design was a direct result of the 1:1 physical buck study. Further ergonomic study will be completed to refine and define the design direction for this thesis project.

3.5 Analysis - Sustainability: Safety, Health, & Environment

Many elements of the concepted design contribute to preserving the physical and mental health of its users. Maglev technology eliminates nearly all local pollutants including air, water, and noise (Northeast Maglev, 2020; Retzmann et al., 2012). Pollution is reported to be linked to over 9 million deaths worldwide each year, most of which are occurring in urban environments - addressing vehicle pollution through the elimination of privately owned vehicles in urban environments should drastically reduce illness and death among urban inhabitants (Fuller et al., 2022).

Primary research methods identified users maintaining a connection with the outside world as a contributing factor of happiness for commuters. Users value windows while commuting, and this leads to an integral component of the concepted design solution - open-air travel. This initiative is about connecting the rider experience with the outside environment by eliminating barriers. Weather permitting, the default configuration of the vehicle has its side windows fully lowered to accommodate a physical connection with natural and urban environments outside the vehicle. Seating configurations are aligned to provide every seated rider with a view out the window. Additionally, the proposed systemic design relies heavily on mixed travel, creating a more active commuter lifestyle. Ultimately, this intends to create a more valuable travel experience leading to less commuter depression (Marques et al., 2020).

Notable safety features of the concepted design include the benefits of automated vehicle operation systems and featured material functions. Automated systems aim to eliminate human error (Glas, 2020). The concepted transportation system relies on driverless vehicles communicating autonomously to increase efficiency and safety. Ideally, this system can eliminate all vehicular accidents that are not derived from part failure. Maglev vehicles rely on far fewer mechanical parts, leading to comparably minimal points of failure.

A number of material features contribute to a safe rider experience. This includes UV and heat protection technology in windows and doors (Glass for Europe, 2017). Additionally, traction is integrated into the wood coating of the floor to reduce slipping, and multiple points of the vehicle feature weight-bearing handles to support user weight and aid balance during vehicle movement.

The conceptual thesis “Rethinking Urban Transportation” creates sustainable initiatives in many aspects of the design. The design relies on material and manufacturing innovations to improve user experience and environmental impact. Technology implementation and systemic design choices like maglev and driverless cities create a heavily reduced environmental impact during operation. Material and manufacturing components are designed to be durable, replaceable, and sustainable. Together these sustainable initiatives create a socially responsible vision of the future of public transportation.

3.6 Analysis - Innovation Opportunity

Through user research, product research, initial concept development, and human factors testing an opportunity to innovate became more clear. This section will address user needs as they relate to a unique design opportunity.

3.6.1 Needs Analysis Diagram

Table 21

Needs Analysis Diagram

Needs	Benefits and Underlying Needs	Level of importance		
Basic Needs				
Food, water, shelter	Riders seek shelter and travel inside a transportation vehicle		Moderate	
Pleasure, gratification	Serenity while travelling, comfort in seat, gratitude for peaceful moment		Moderate	
Security				
Safety	Degree of safety is expected in public spaces			High
State, group, individual	Public transportation is a state-funded system, taxpayers have expectations for security		Moderate	
Securing resources	High taxpayer cost associated with transit, fares can be additional, cost-effective			High
Control over environment	Users should experience transit actively, good interaction is no interaction		Moderate	
Long term security/stability of group	Massive costs associated means solutions should have decades of stability			High
Social Belonging				
Fear of abandonment	System needs to be maintained	Slight		
Fear of the enemy	Public spaces have an inherent degree of safety concern, individuals can cause harm		Moderate	
Tribal identity	Transportation is the lifeline of a city, the solution should relate to the local identity			High

Behavior cues for survival	Mechanical danger, potential for injury		Moderate	
Behaviour cues for social interaction	Users should have the option to be social or private			High
Social expectation	The solution can create a social expectation for travel in the affected area			High
Esteem				
Social status	Public transportation in some cities is a “great equalizer” of status		Moderate	
Social recognition	Recognition will come from the population that lives outside of the system	Slight		
Sexual attractiveness	Beauty in terms of city planning and visual design, integration with the utopic city of the future			High
Self-actualization				
Intrinsic pleasure	Living in a beautiful environment (city), efficient travel, connection			High
Creative endeavors	Opportunity to create while travelling		Moderate	
Experiential (extrinsic)	Travel, city of the future		Moderate	
Experiential (intrinsic)	Time spent travelling		Moderate	
Emotional	Human experiences while travelling		Moderate	

Chapter 4 - Design Development

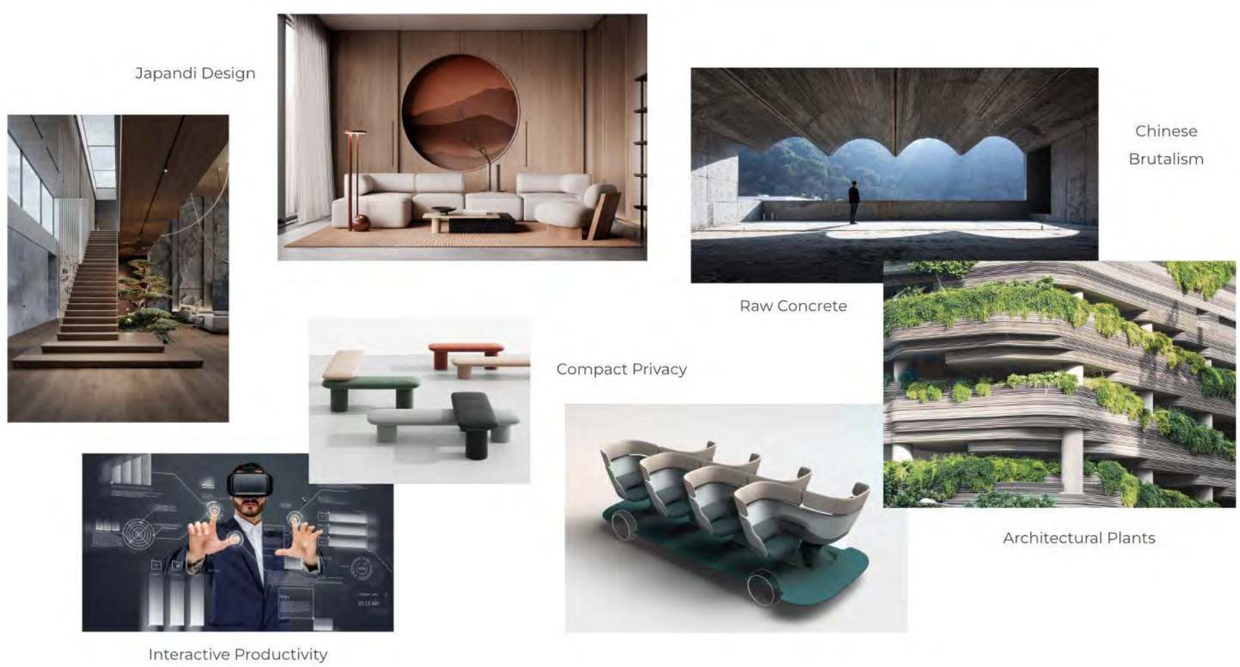
4.1 Initial Idea Generation

The development phase of this project was prolonged and challenging. Balancing the intentions to innovate in a system environment, user experience, form design, digital experience, and technological level created a complex development phase. This chapter will summarize the progression of design leading up to design finalization.

4.1.1 Aesthetics Approach & Semantic Profile

Figure 15

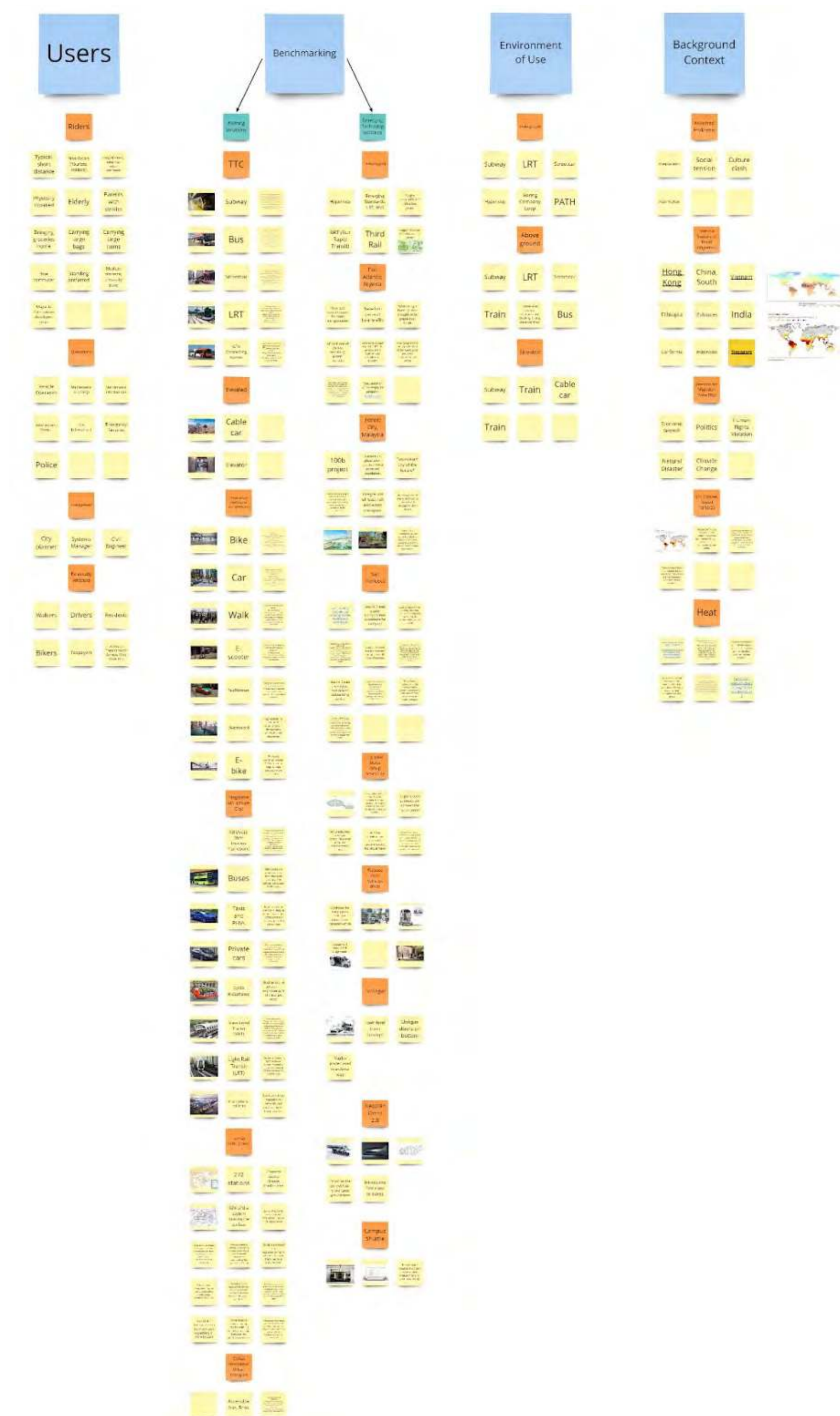
Mood Board for Design Development Indicating Aesthetics and Semantics



4.1.2 Mind Mapping

Figure 16

Mind Mapping Throughout Design Research, Miro Board



4.1.3 Ideation Sketches

Figure 17

Ideation Sketches, Vehicle

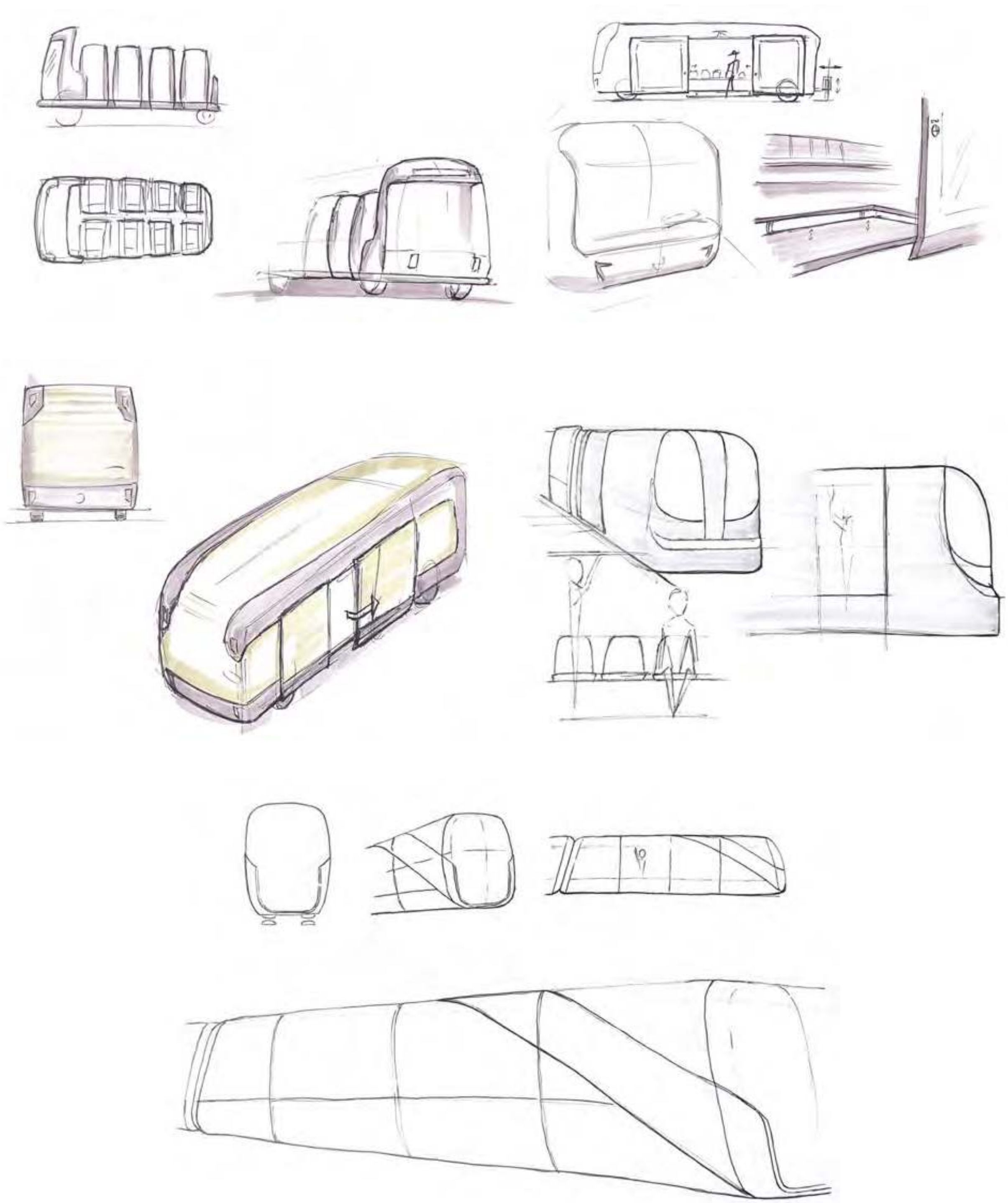


Figure 18

Ideation Sketches, Floorplan

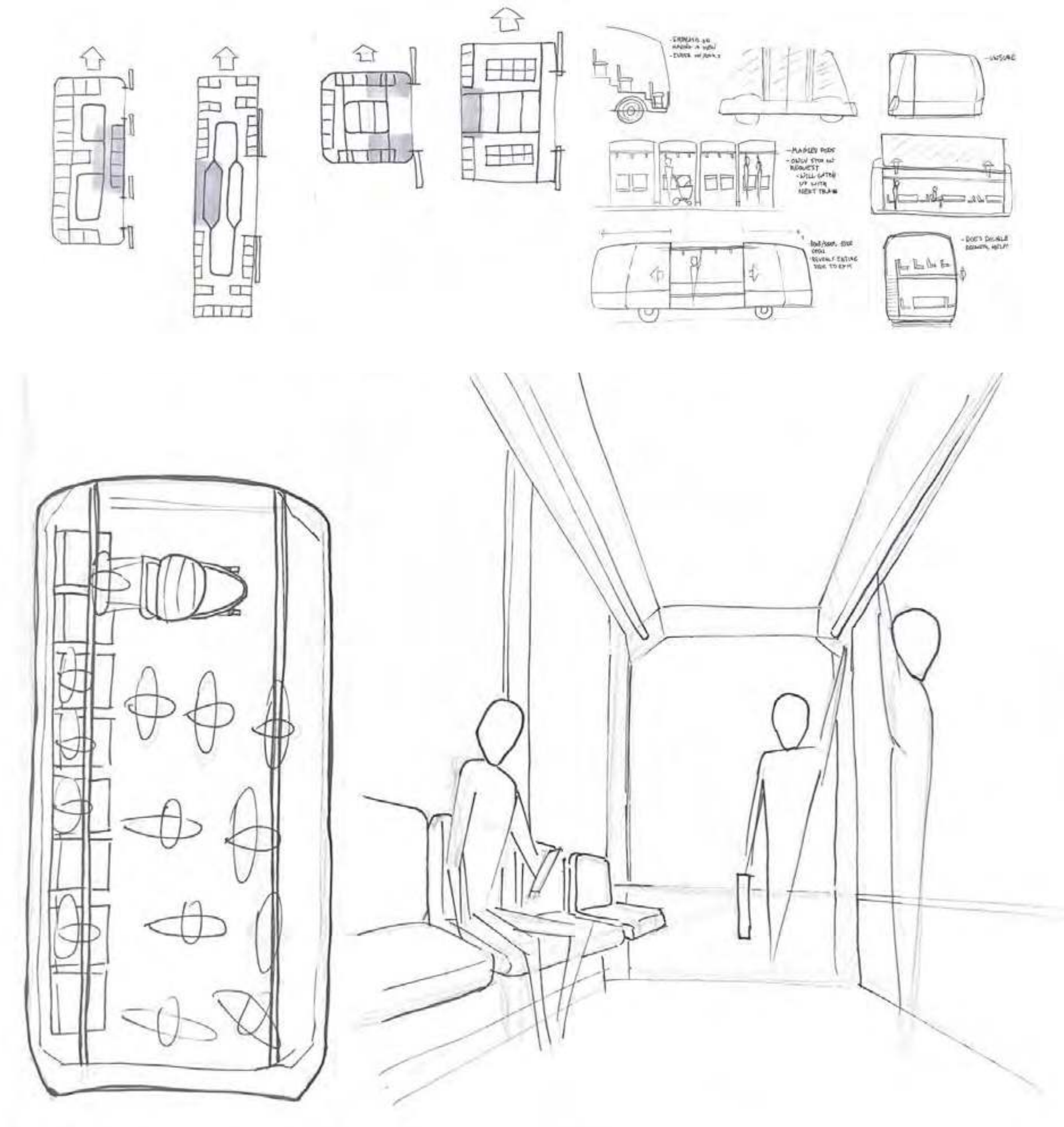


Figure 19

Ideation Sketches, Street Level Integration

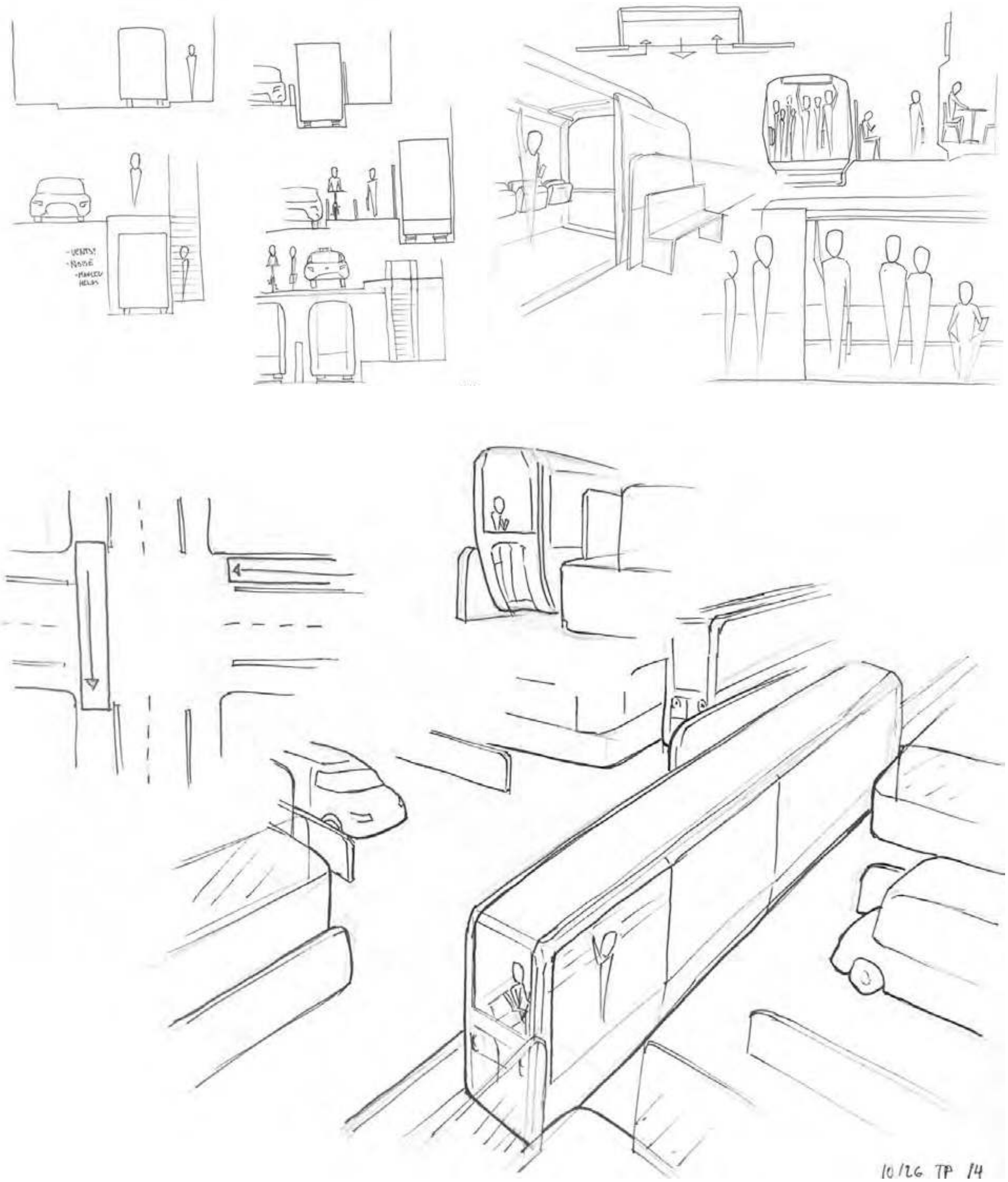
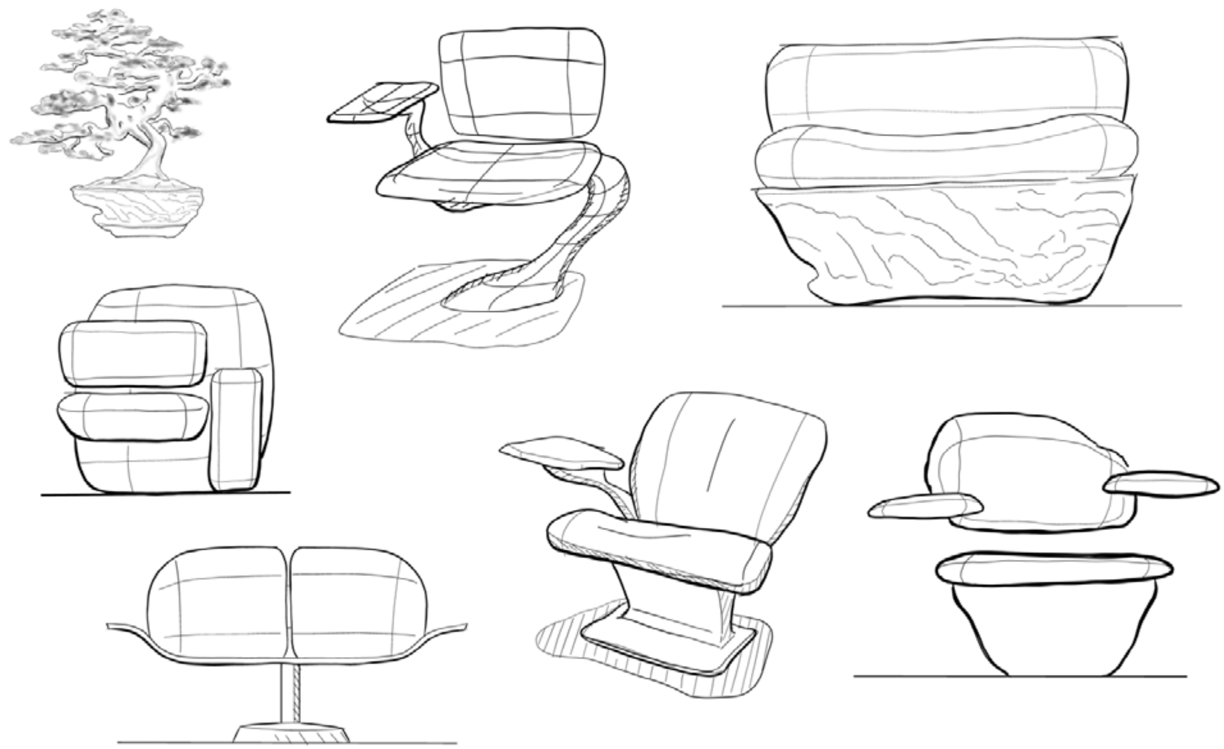


Figure 20

Ideation Sketches, Furniture

Figure 21

Ideation Sketches, Furniture Cont.

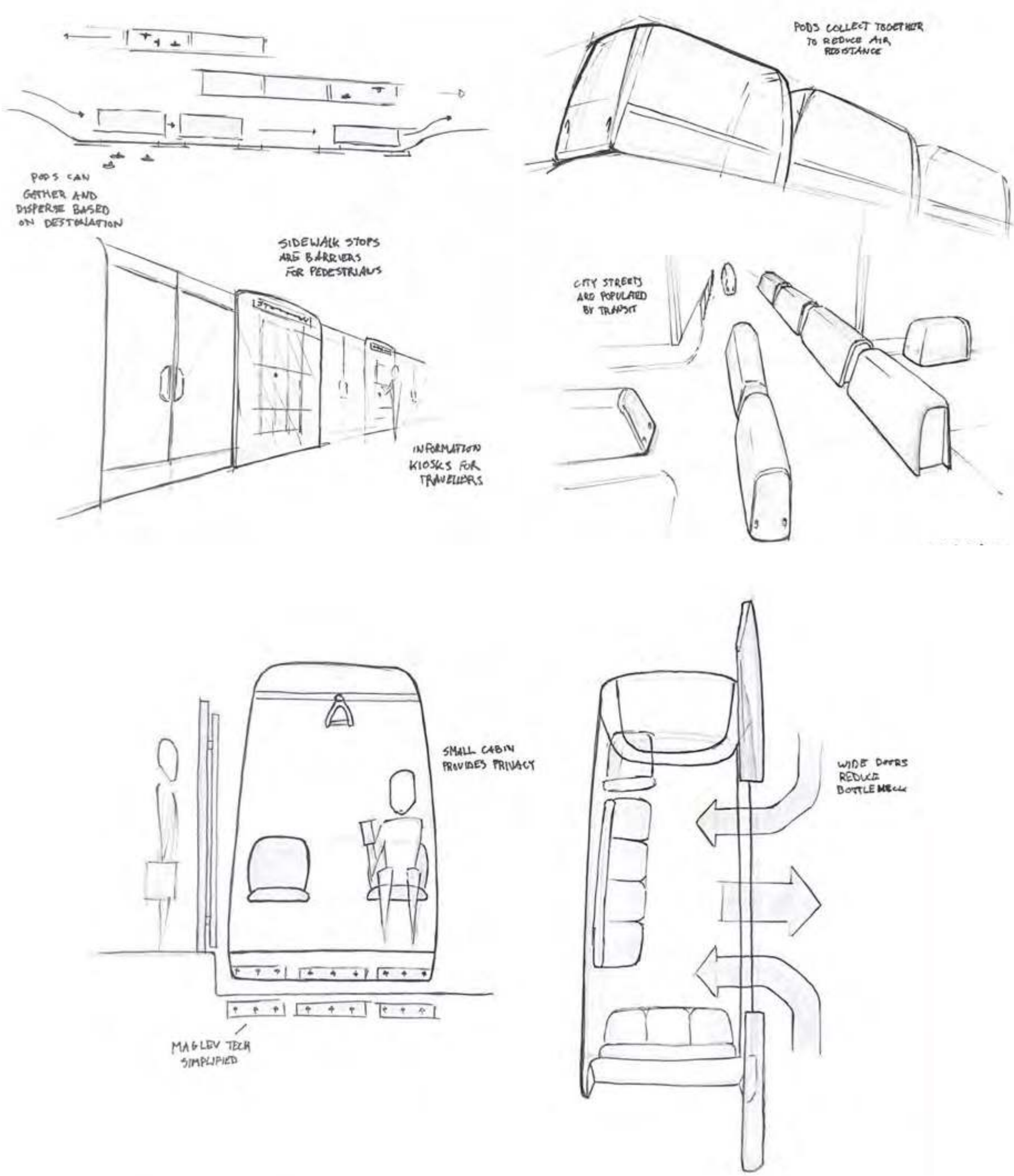


4.2 Concepts Exploration

4.2.1 Concept One

Figure 22

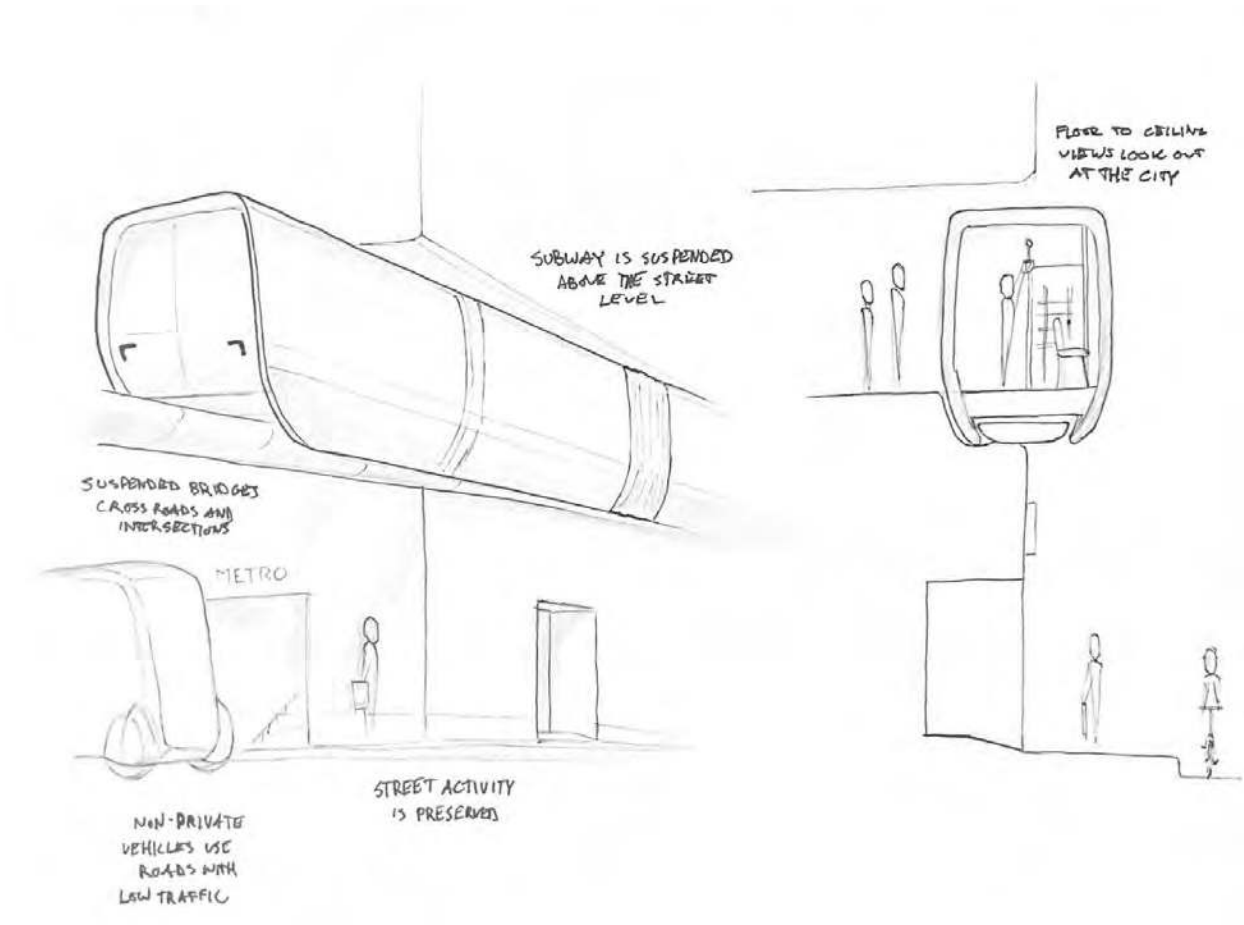
Modular Street Train



4.2.2 Concept Two

Figure 23

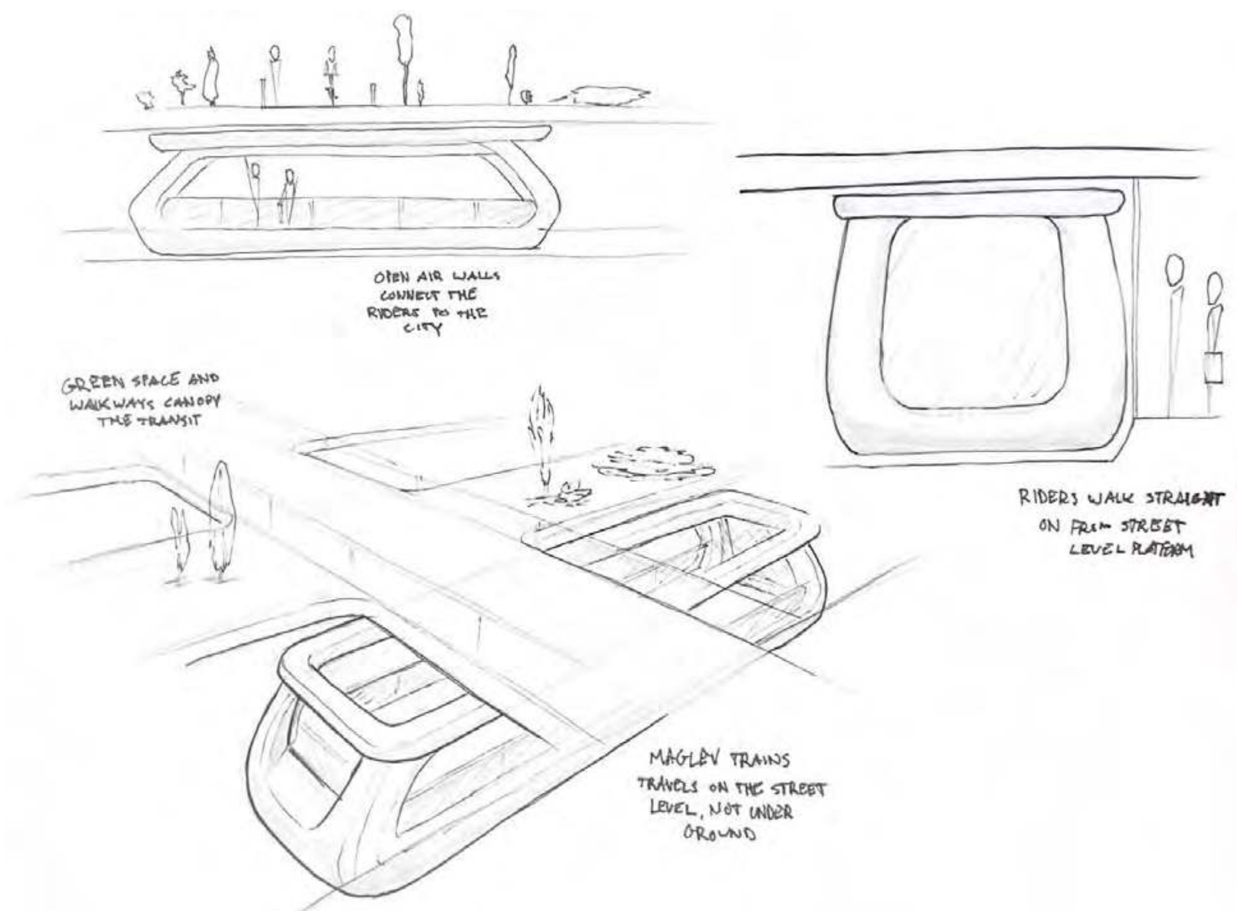
Suspended Urban Train



4.2.3 Concept Three

Figure 24

Greenspace Streetcar



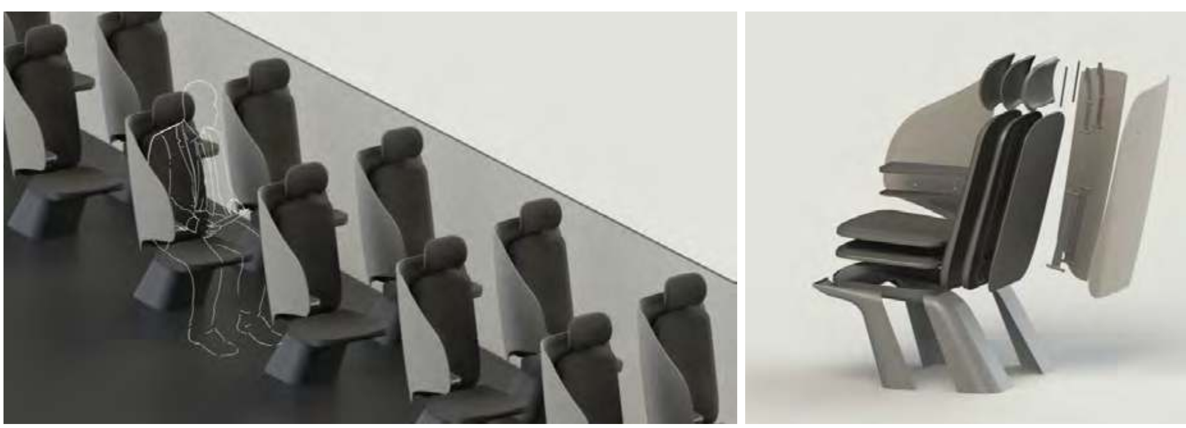
4.3 Concept Strategy

Beyond initial concept exploration two distinct design directions were further developed. Using the structure and design intentions of concept exploration one and three initial interior designs were presented to the thesis panel. Concept one features the Open-Air Streetcar exploring the user connection between travel and nature in an urban environment. This design also encourages the use of mixed-mode travel and the first iteration of the final design's privacy seating barriers. Concept two further refined the initial exploration of a convoy-based train system making Maglev propulsion more efficient through a reduction in air resistance. This concept also implemented technology into premium privacy cabins to create a more productive travel experience. Concept direction one was ultimately chosen for its unique approach to user experience unseen in any observed product research.

Additionally, the seating of this concept was developed as a side project for the IDSN Fall 2022 Studio class, as seen in Figure 25.

Figure 25

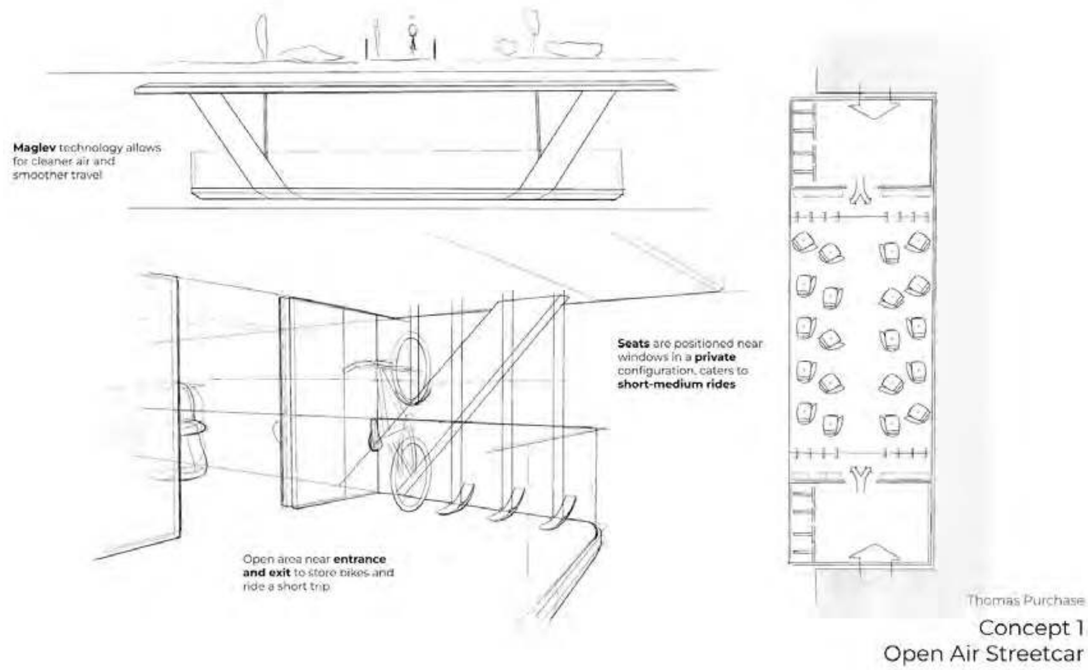
Renders from the Bonsai Public Transit Seat, Covestro Plastic Assignment



4.3.1 Concept Direction & Product Schematic One

Figure 26

Open Air Streetcar



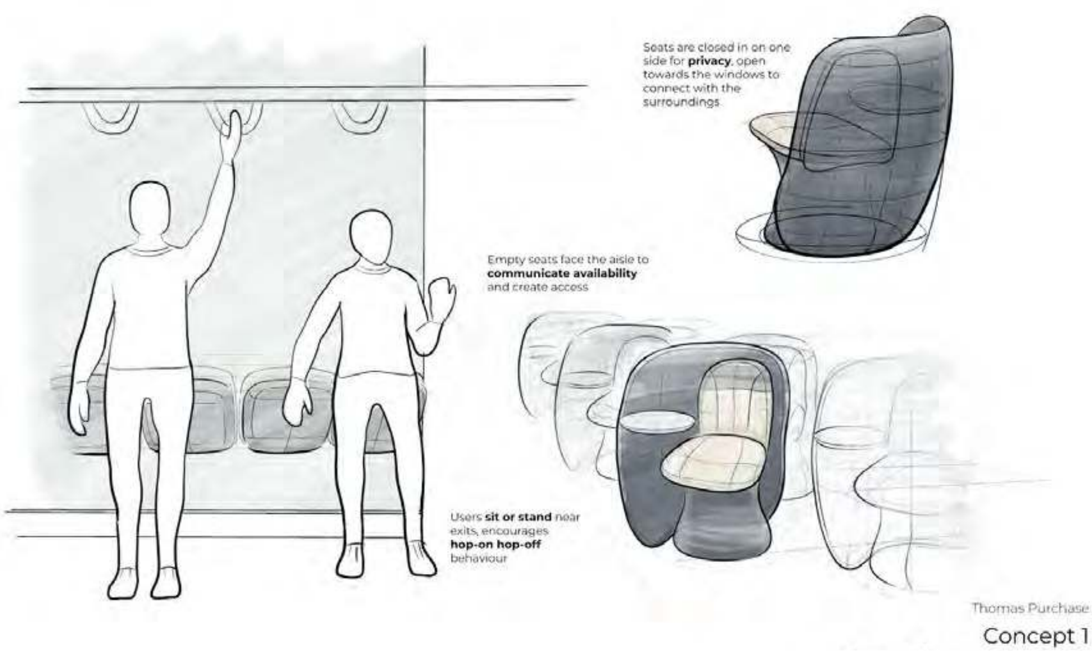
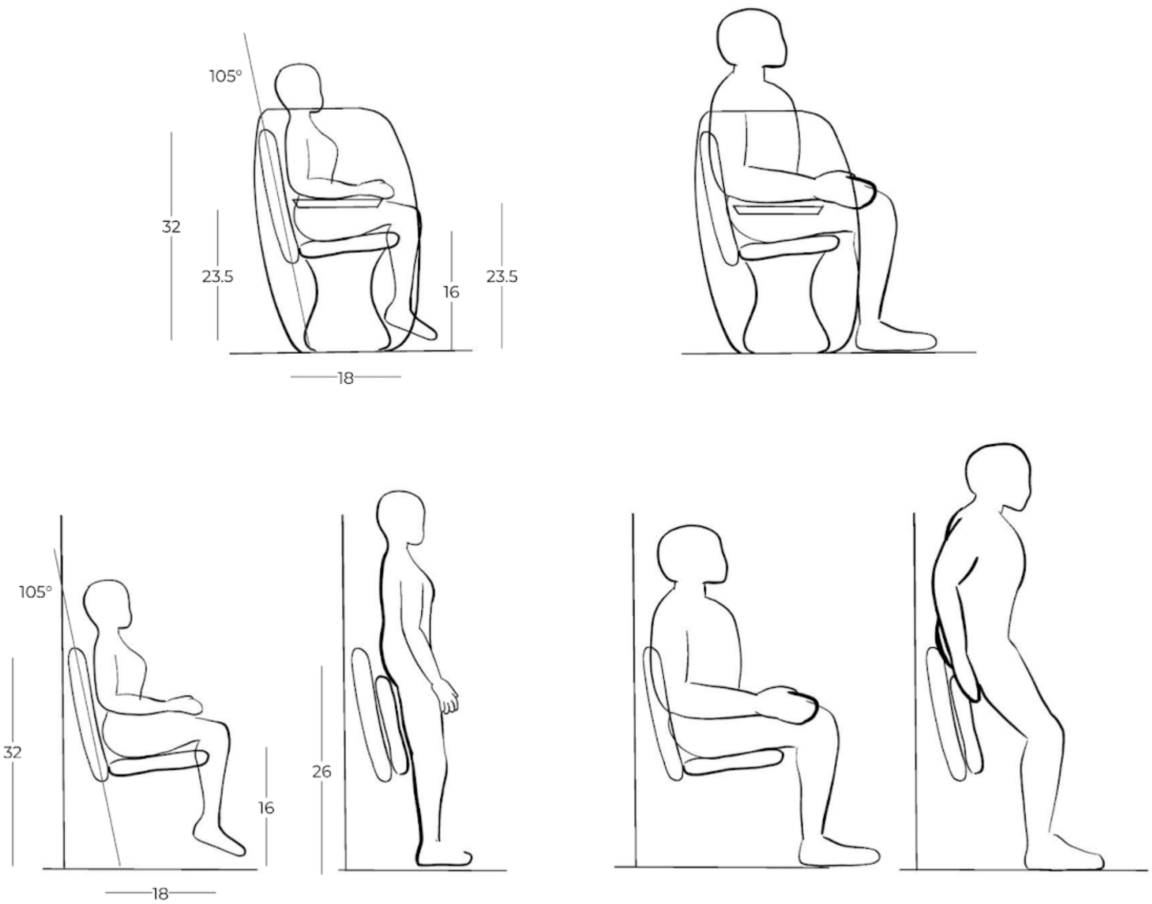


Figure 27

Open Air Streetcar, Schematic



4.3.2 Concept Direction & Product Schematic Two

Figure 28

Modular Street Train

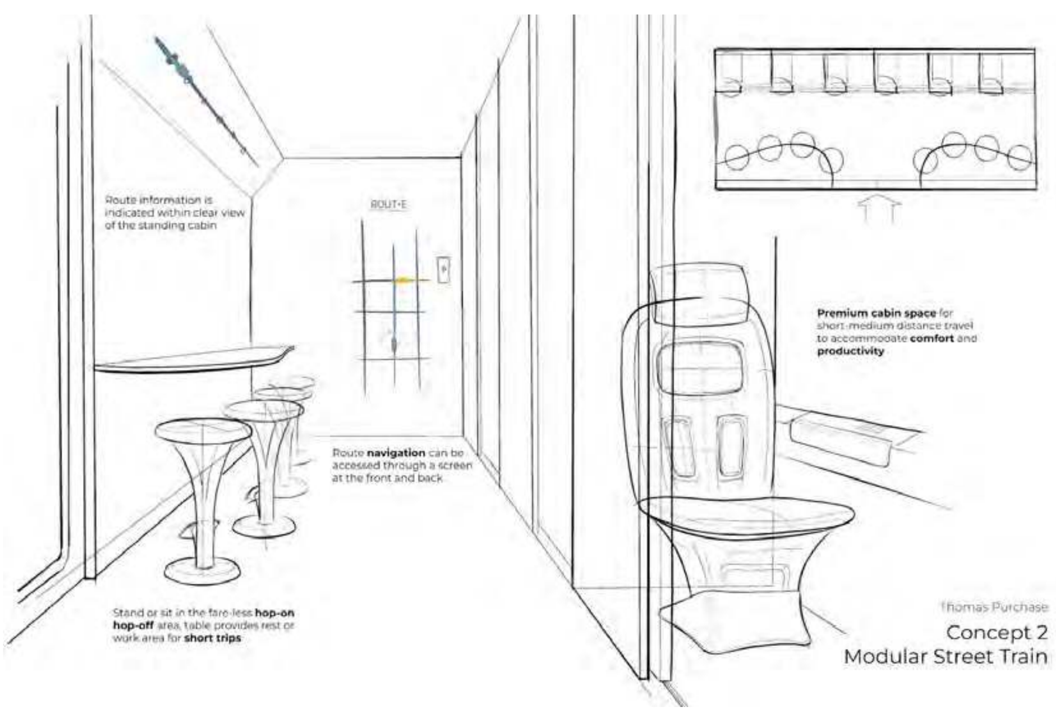
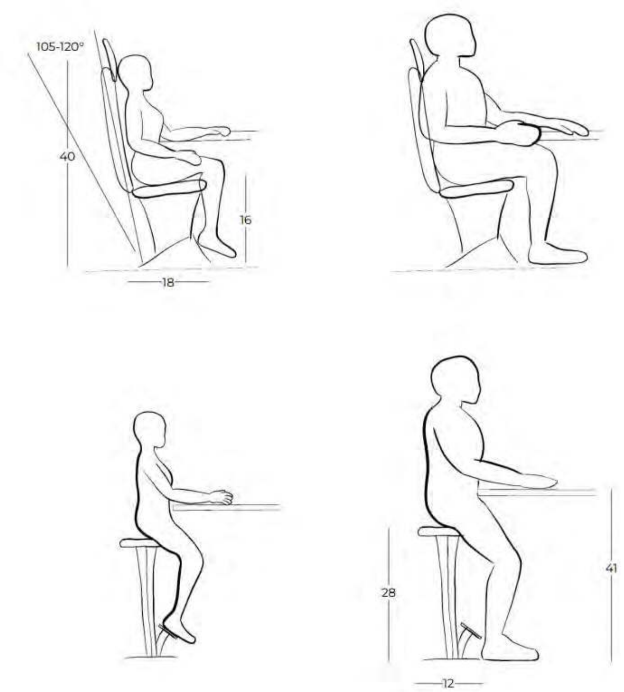
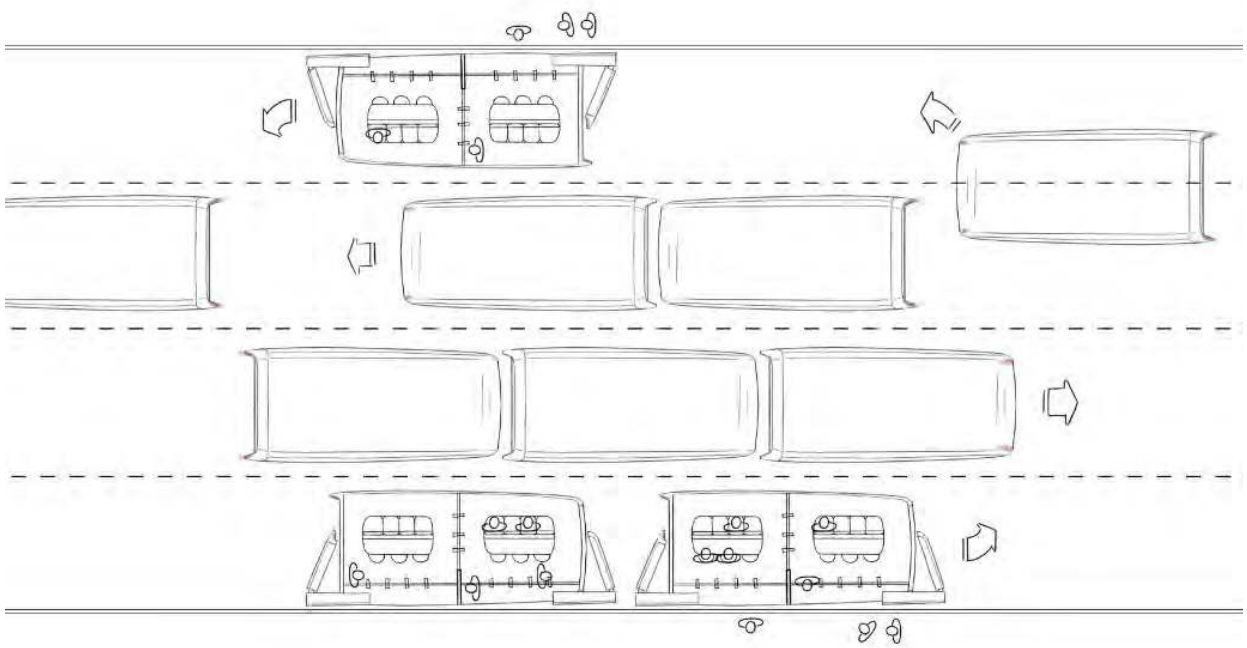


Figure 29

Modular Street Train, *Schematic*





4.4 Concept Refinement & Validation

As previously stated, concept direction one was selected for further concept refinement leading to a final design direction of this thesis project. The concept offered the potential for a unique user experience and styling direction unseen in existing products. This section summarizes the refinement of the chosen vehicle design, seating design, user experience, and design schematic of the selected development direction.

4.4.1 Design Refinement

Figure 30

Design Refinement, Vehicle

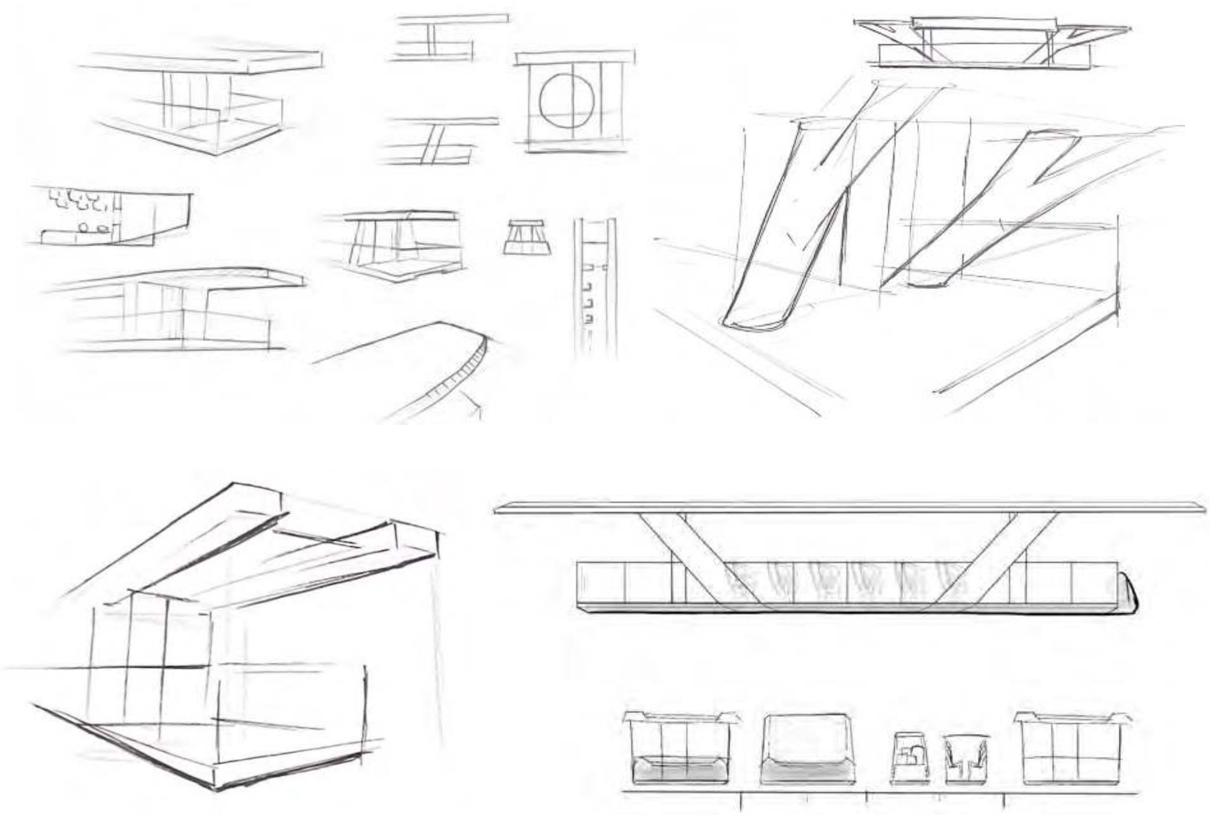


Figure 31

Design Refinement, Primary Seating

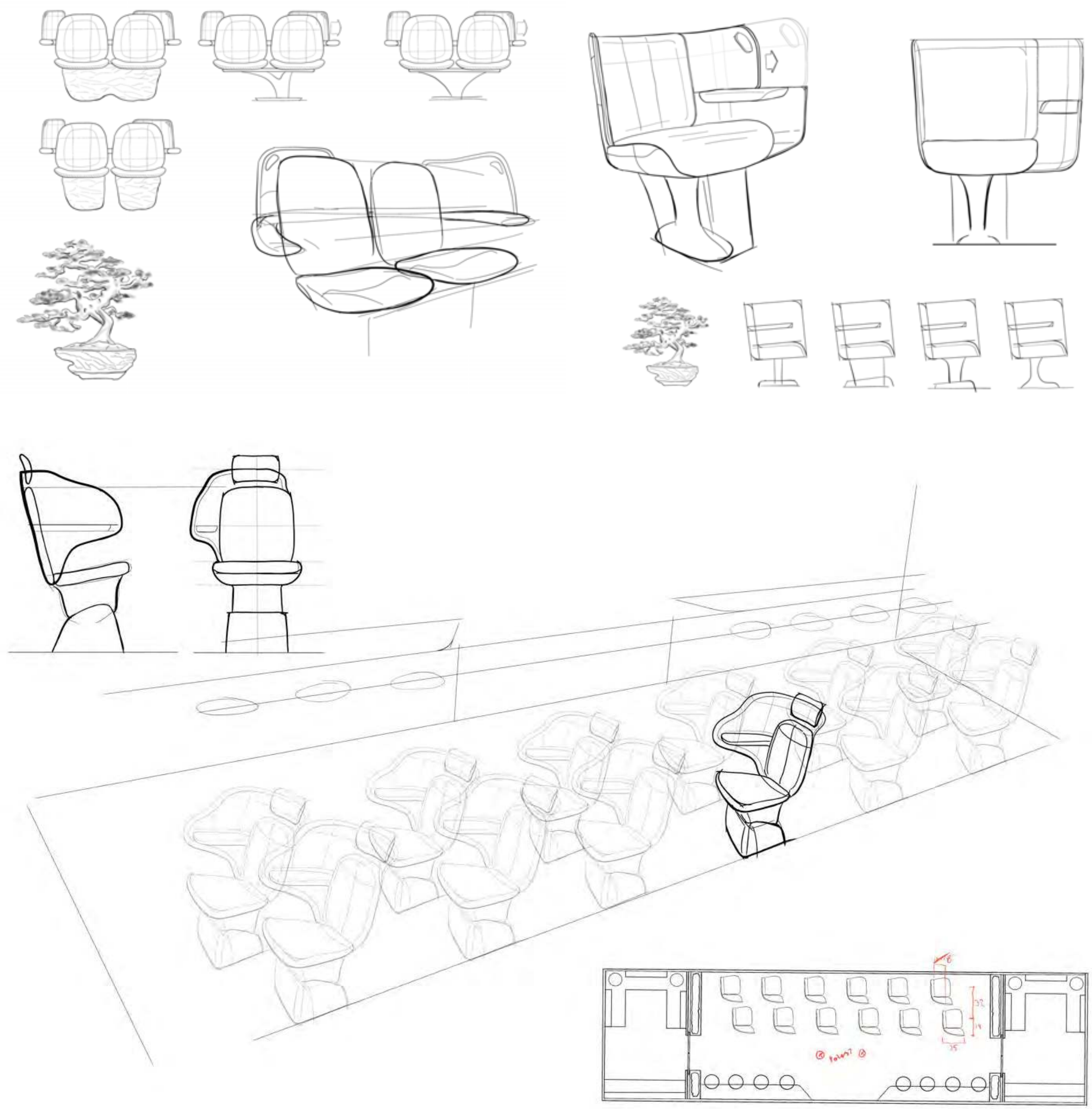


Figure 32

Design Refinement, Primary Seating Cont.

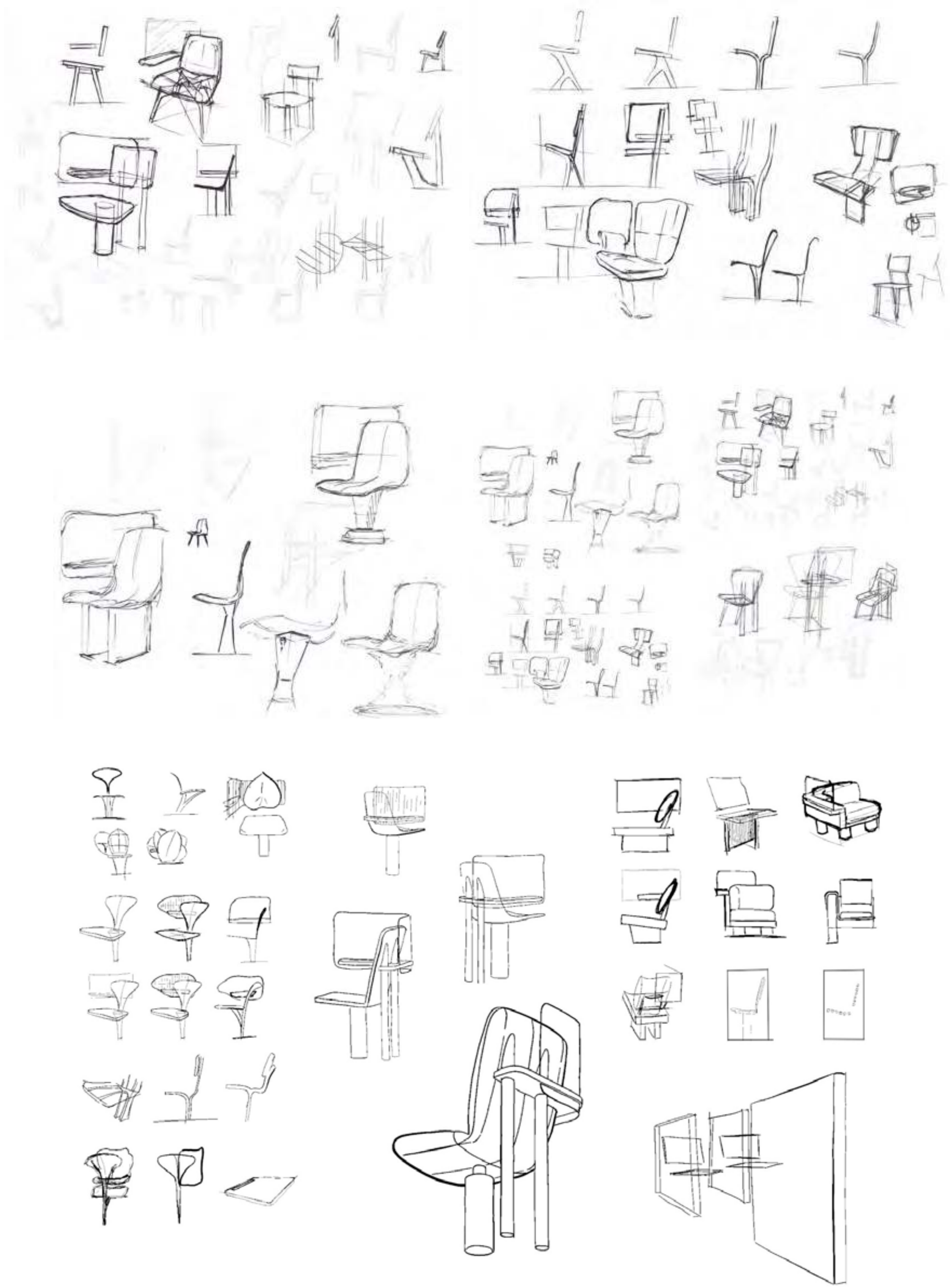


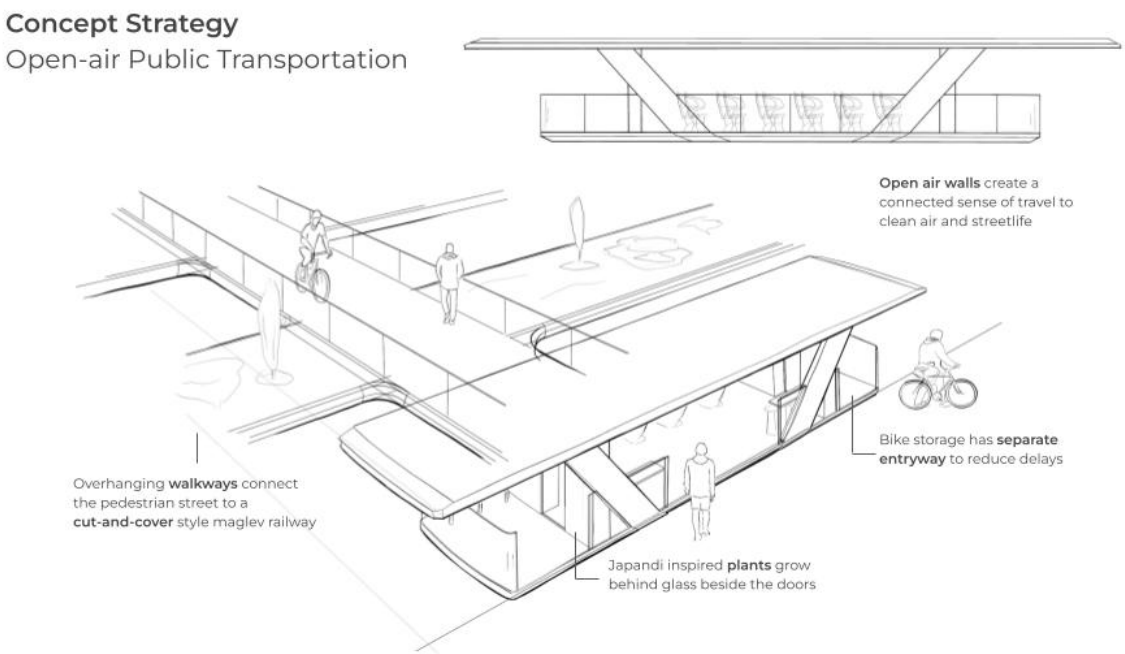
Figure 33

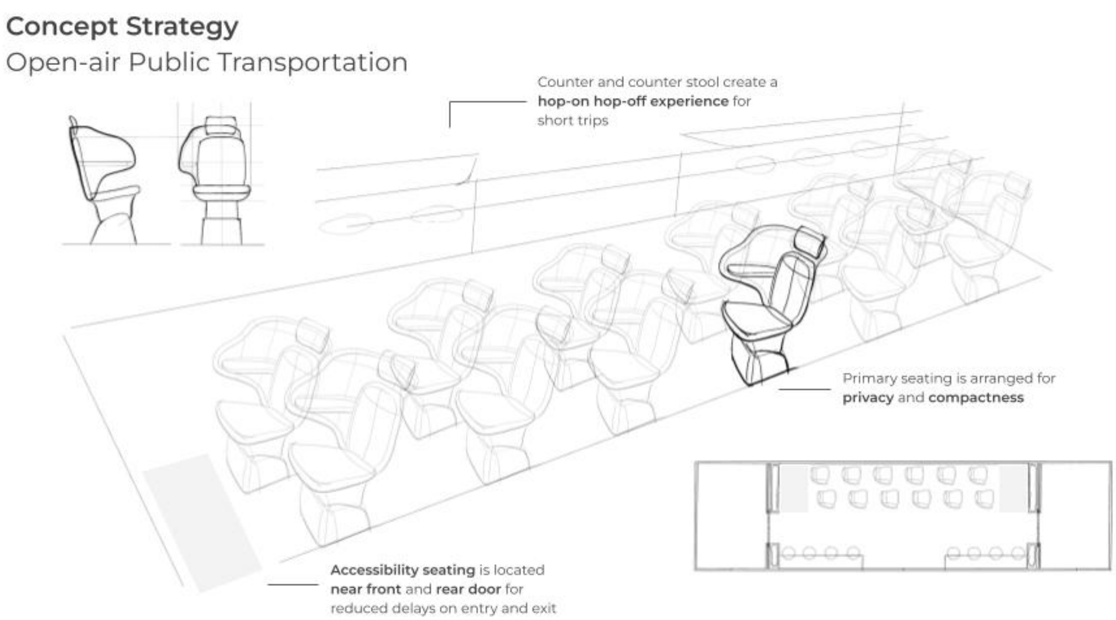
Design Refinement, Stool and Bench

4.4.2 Detail Development

Figure 34

Open-air Public Transportation, Detail Development





4.4.3 Refined Product Schematic & Key Ergonomic

Figure 35

Refined Vehicle and Floorplan Schematic

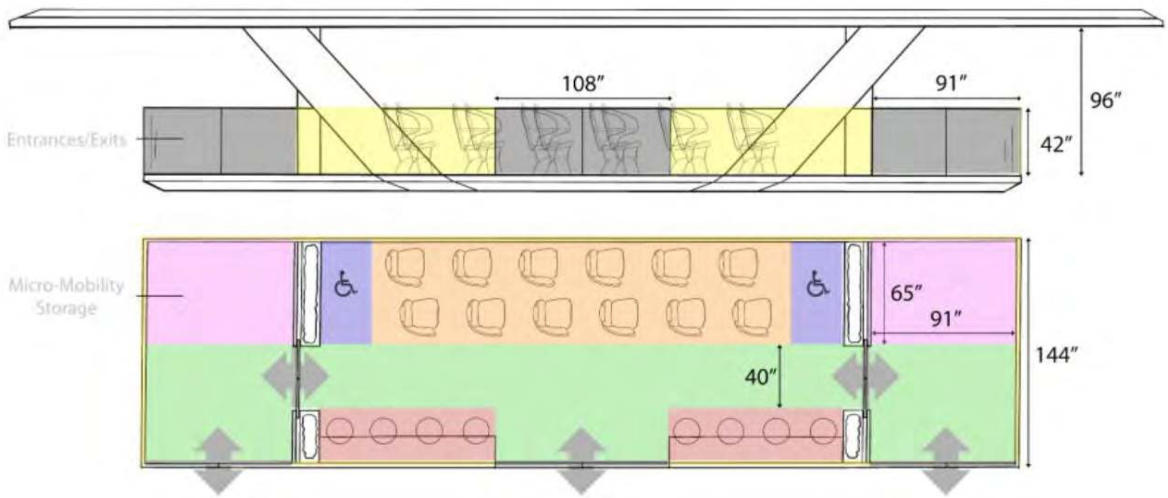
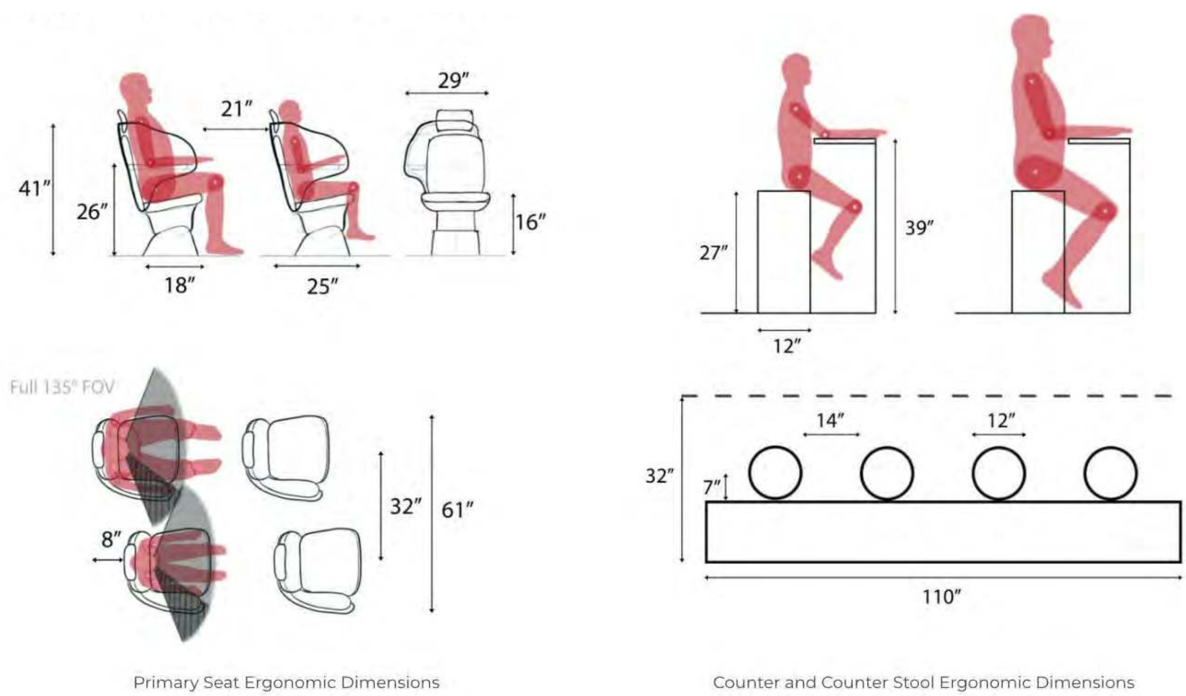


Figure 36

Refined Furniture Schematic



4.5 Concept Realization

This section covers the design refinement leading up to the finalized design. At this stage, the primary challenges included furniture design, floorplan refinement, and exterior detailing. The following figures will showcase the design concept realization including concept sketches, schematics, and a 1:40 scale sketch model study.

4.5.1 Design Finalization

Figure 37

Open-air Public Transportation, Design Finalization

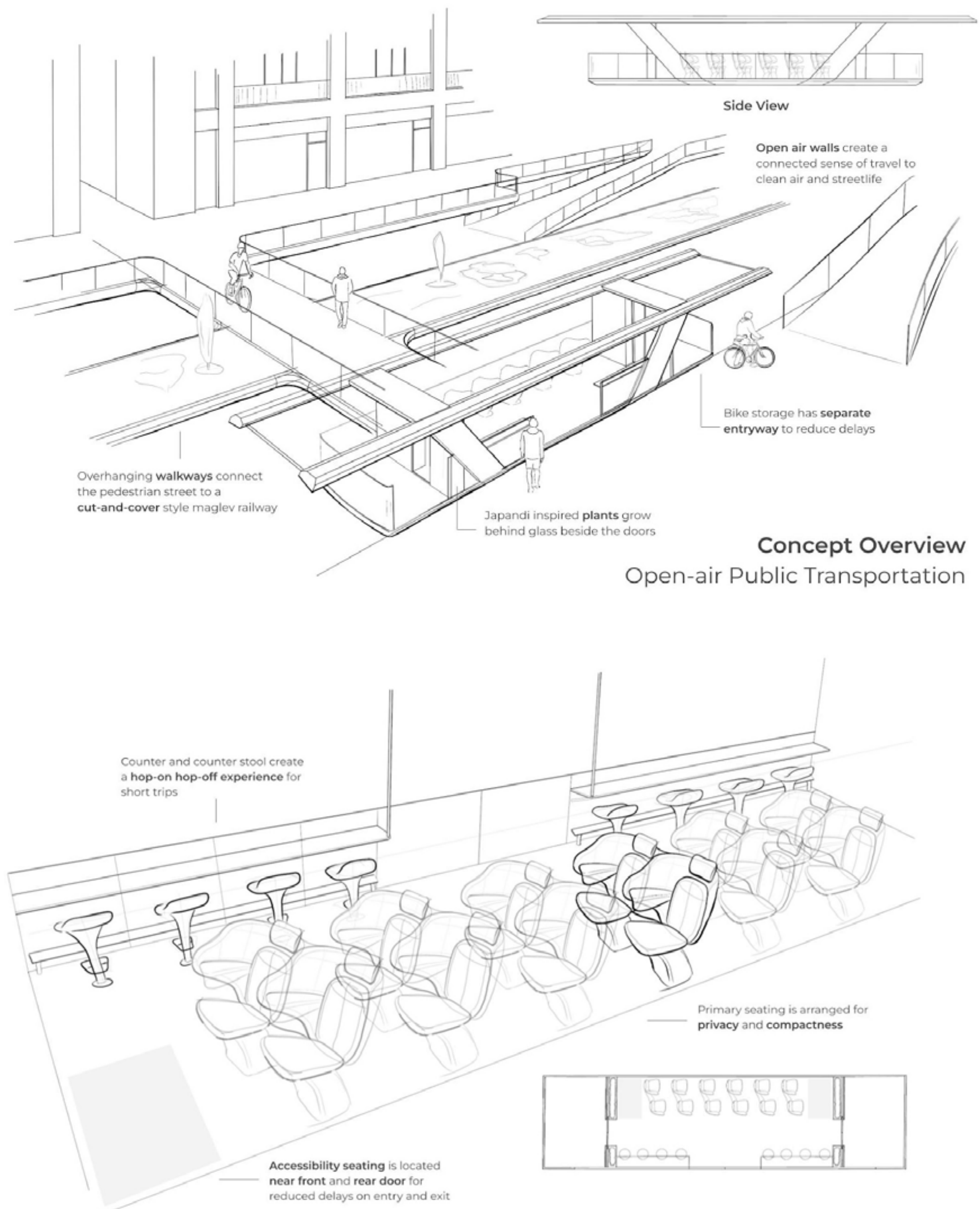
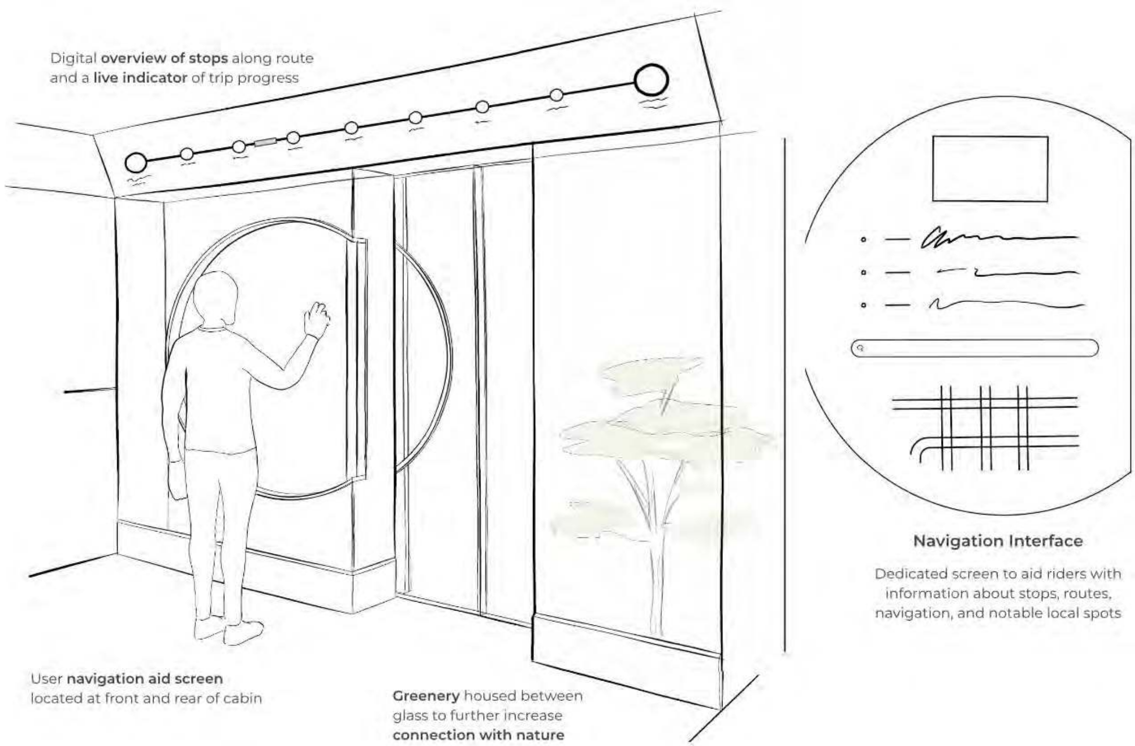


Figure 38

Open-air Public Transportation, Design Finalization Cont.



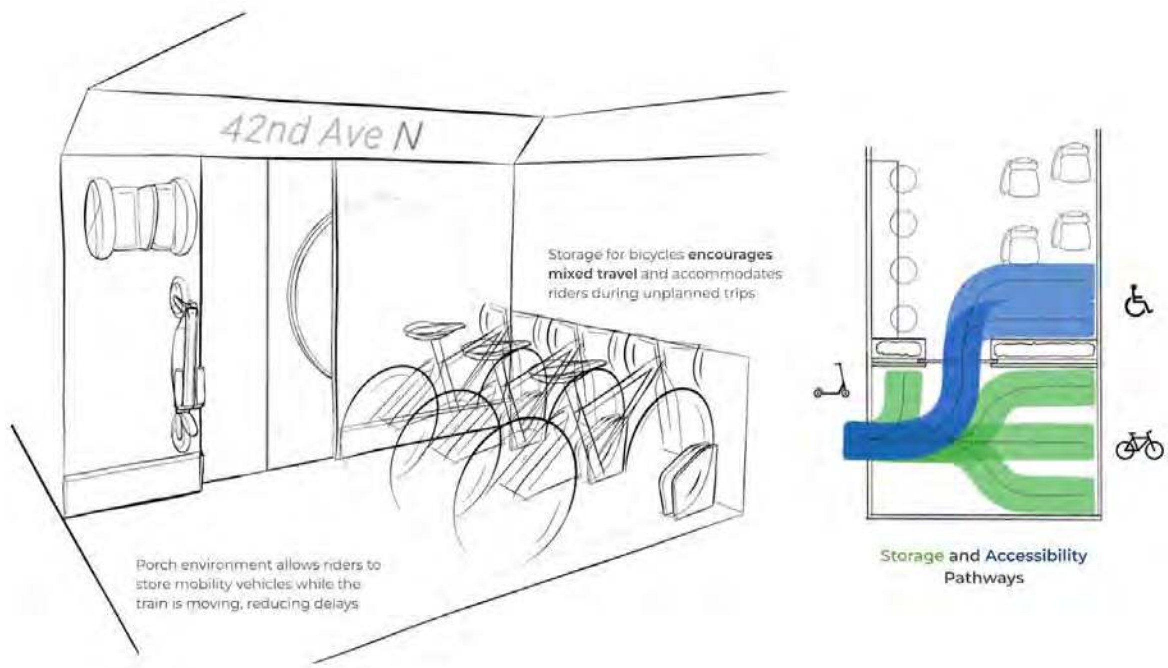


Figure 39

Open-air Public Transportation, Design Finalization Cont. 2

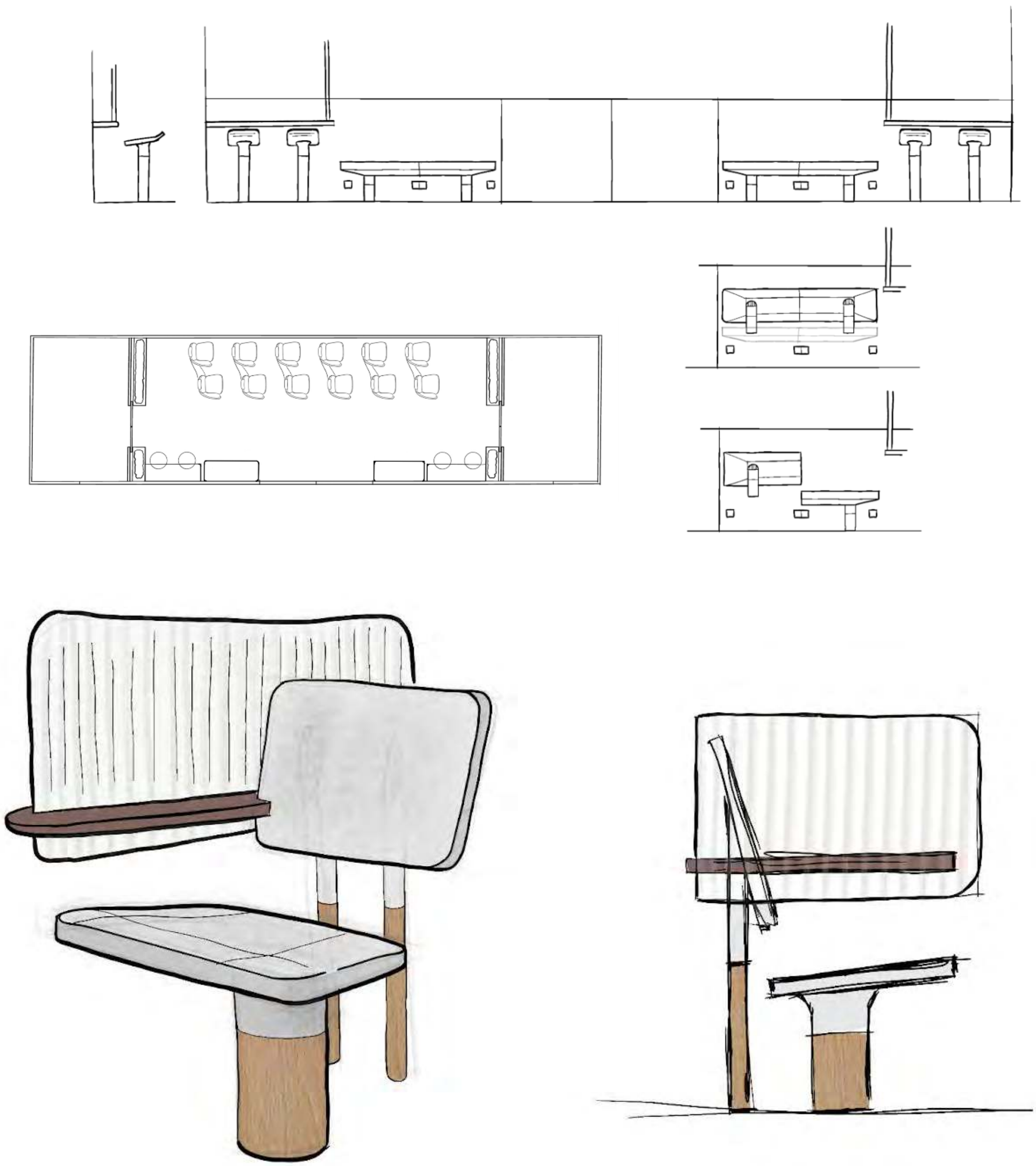
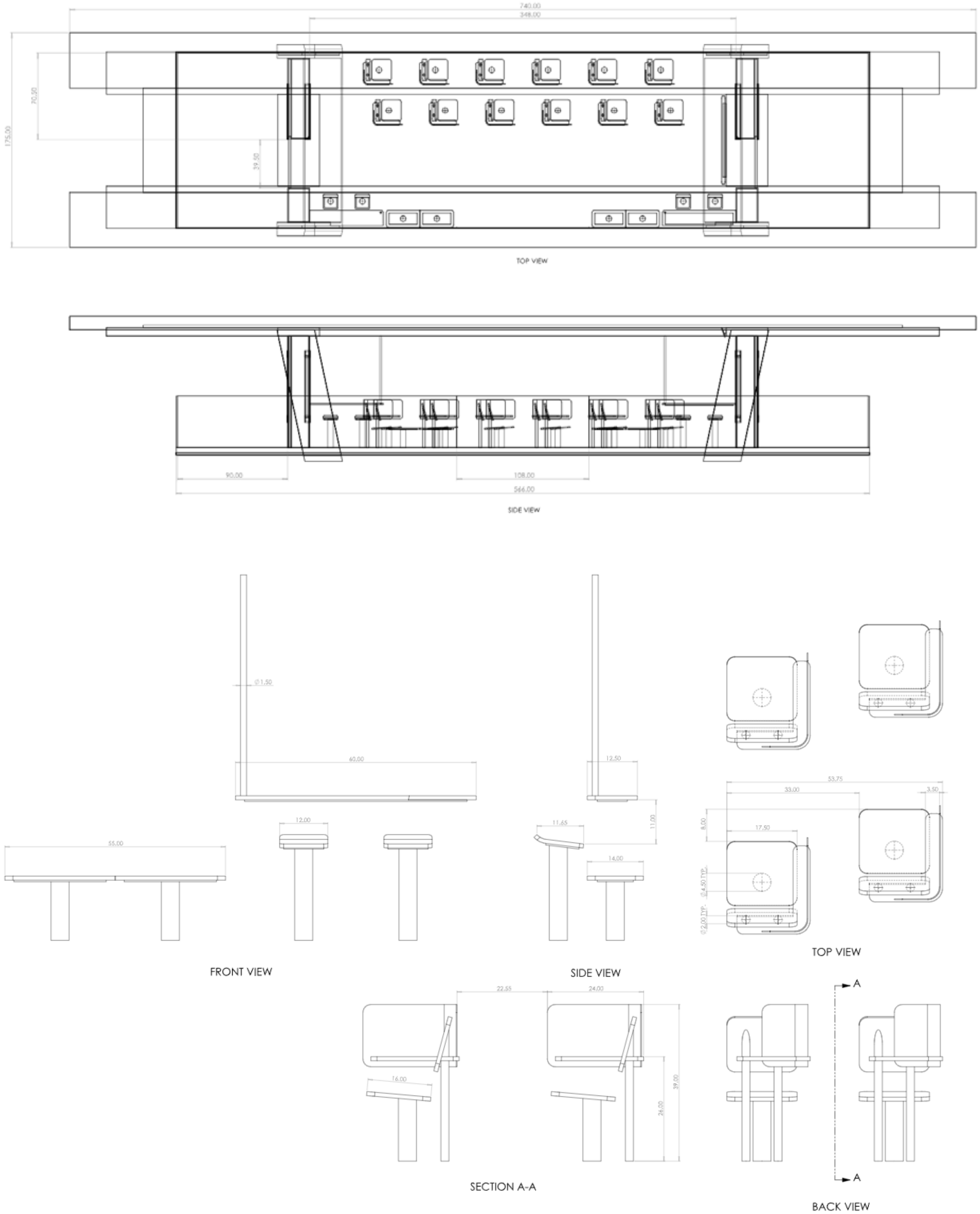


Figure 40

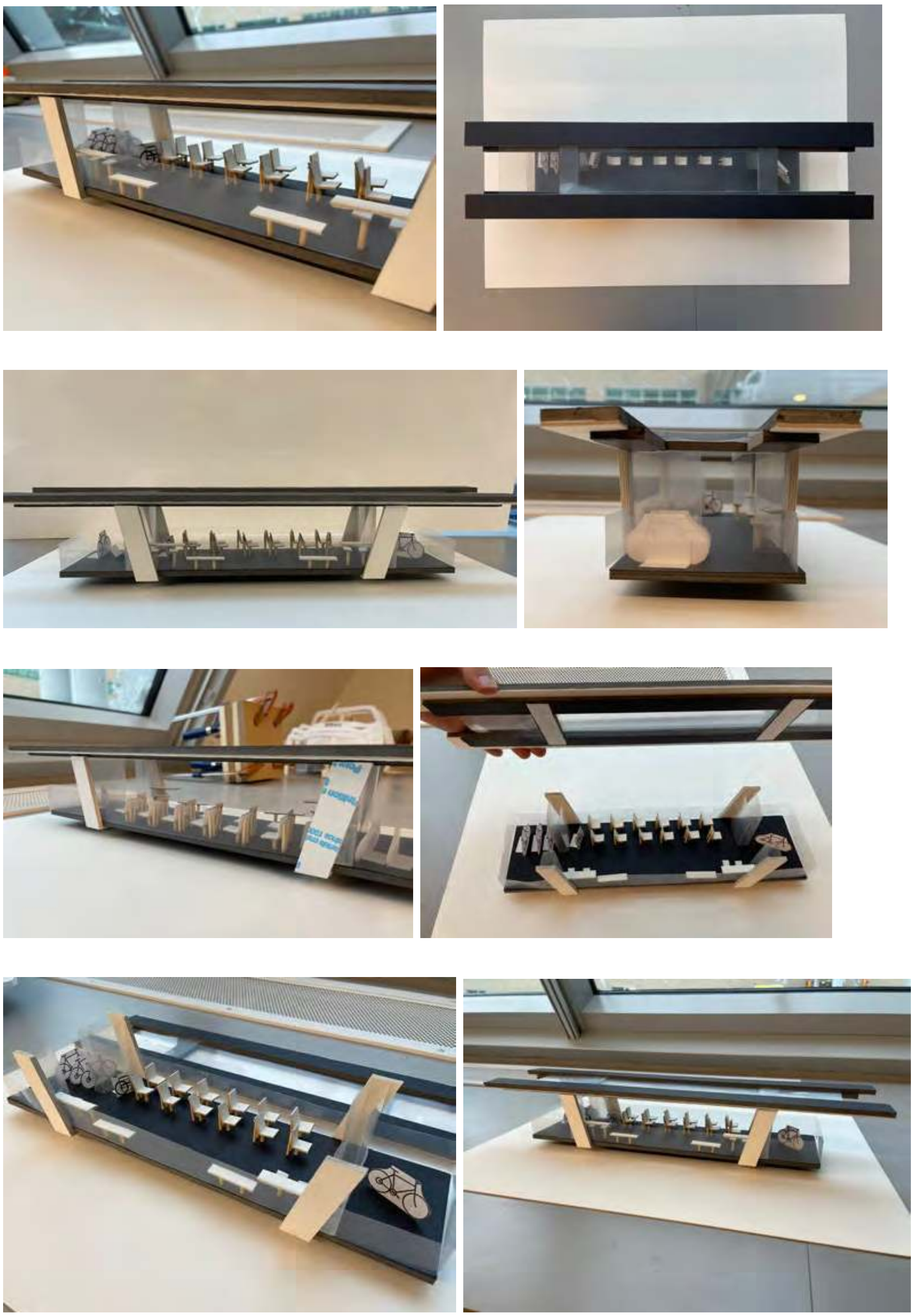
Open-air Public Transportation, Schematic



4.5.2 Physical Study Models

Figure 41

Physical Study Model



4.6 Design Resolution

Figure 42

Open-air Public Transportation, Design Resolution

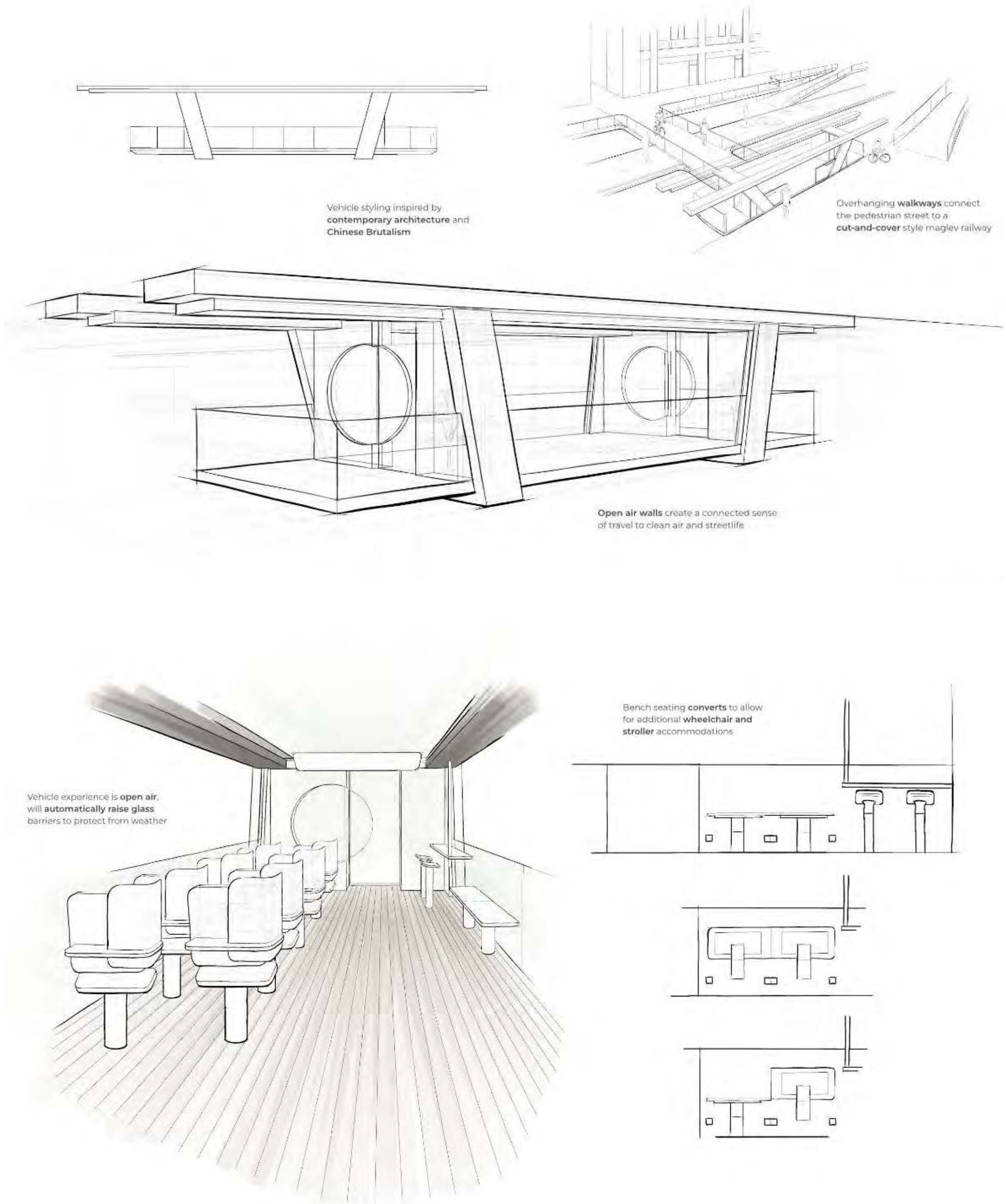
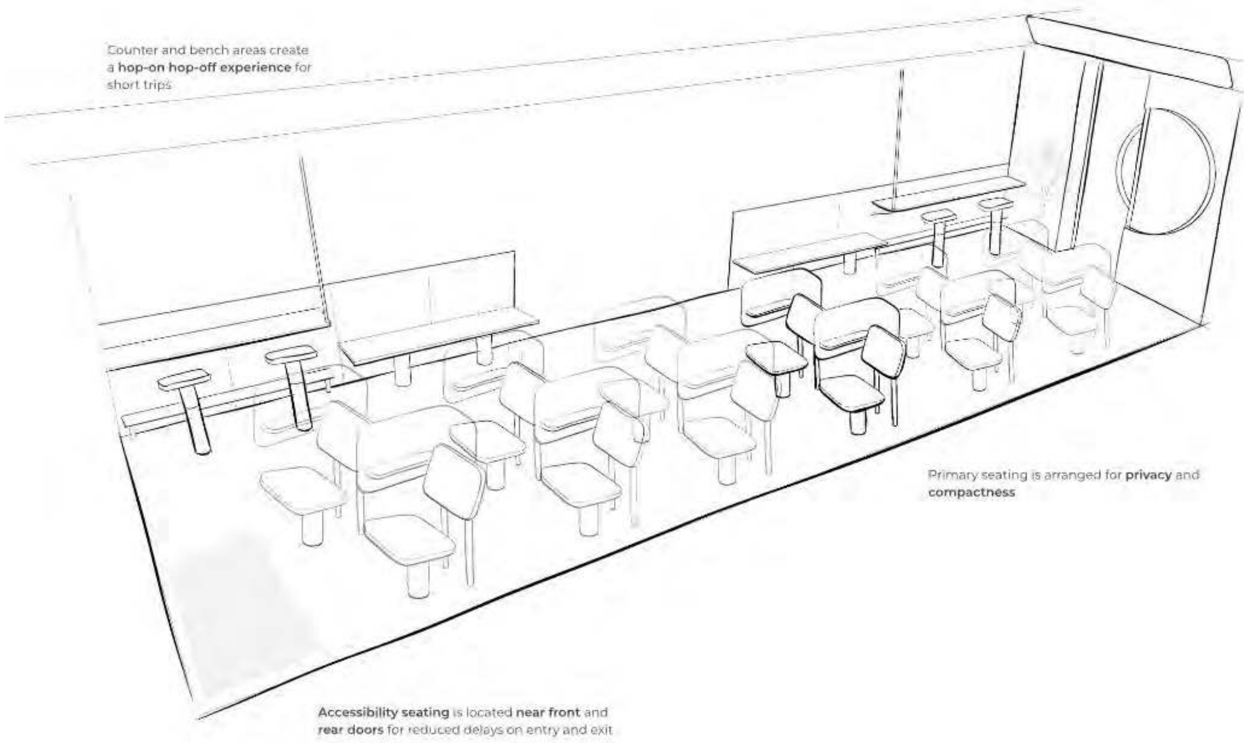


Figure 43

Open-air Public Transportation, Design Resolution Cont.

Figure 44

Open-air Public Transportation, Design Resolution Cont. 2



4.7 CAD Development

Figure 45

Gravity Sketch, Virtual Reality Exploration

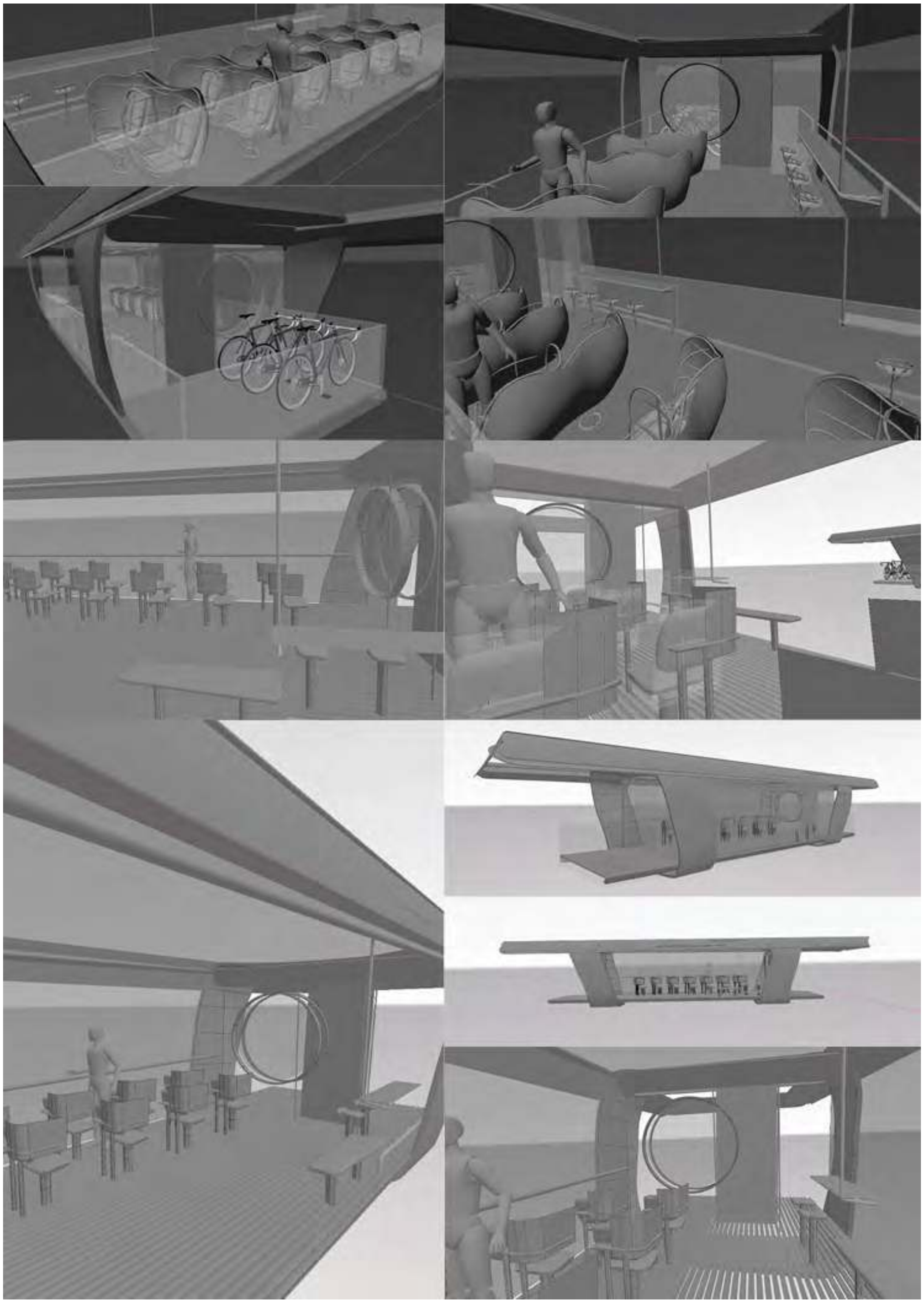


Figure 46

Solidworks, Computer-Aided Design (CAD)

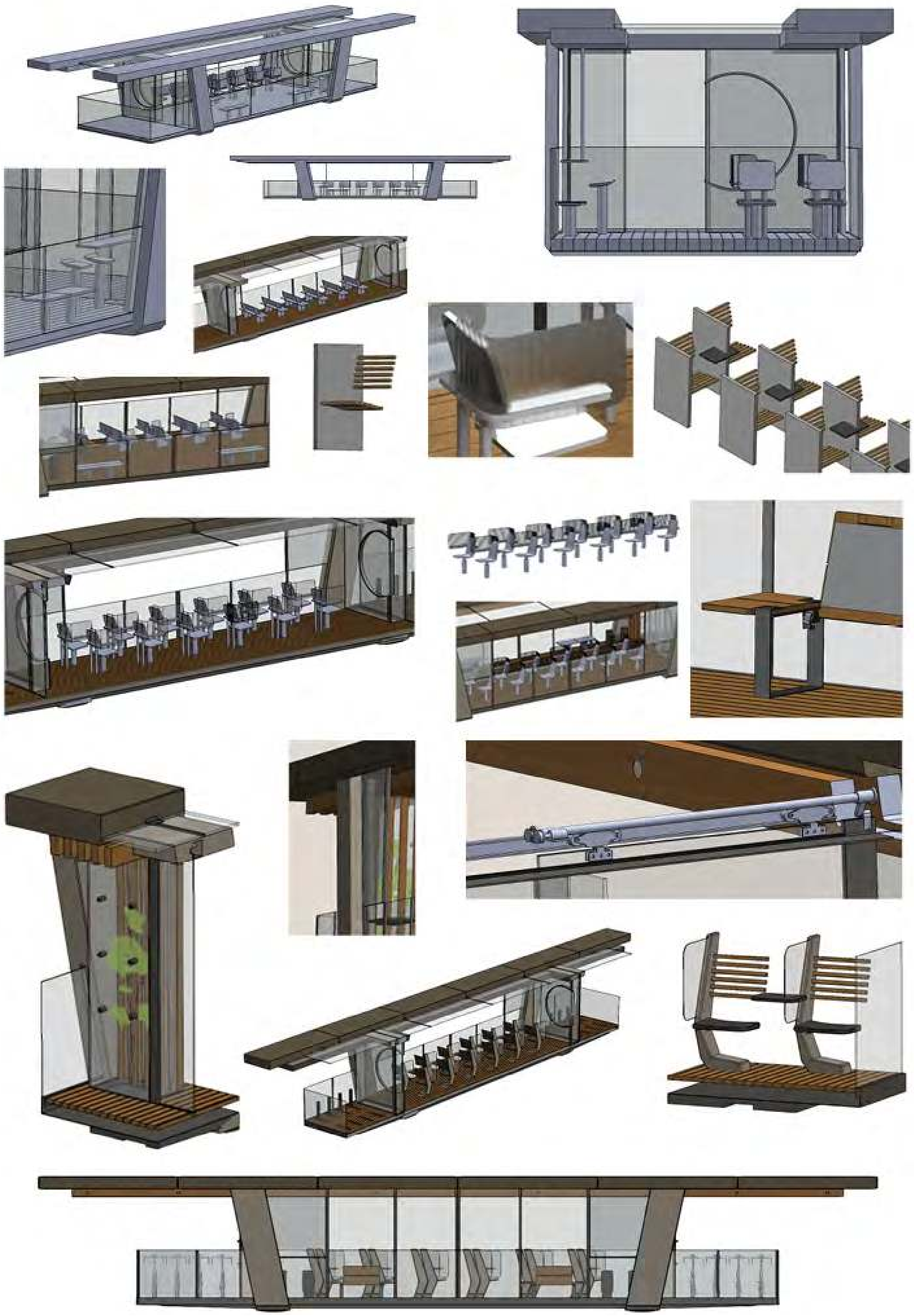
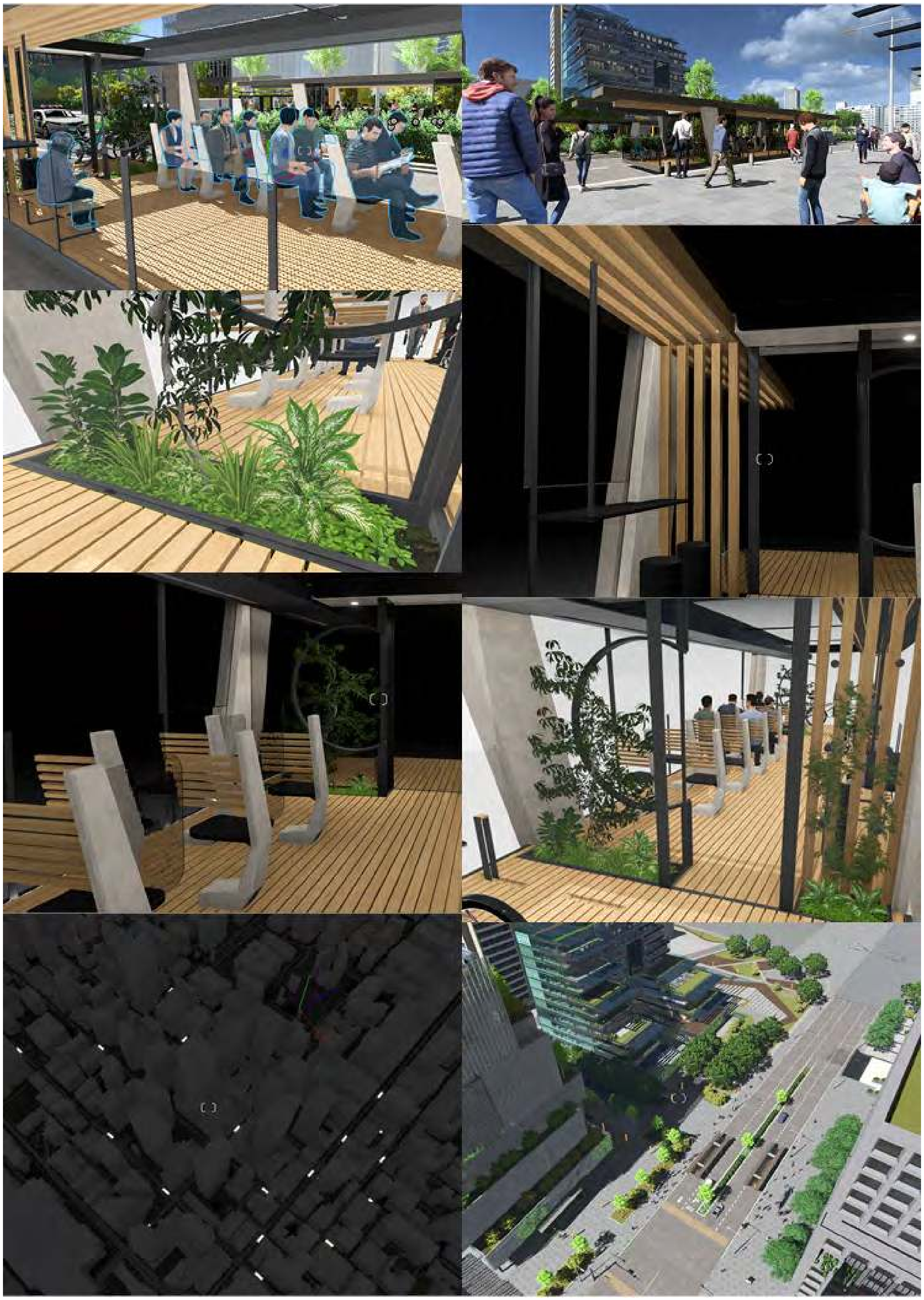


Figure 47

Lumion, Architectural Rendering and Asset Population



4.8 Physical Model Fabrication

Figure 48

3D-Printed Model Parts and In-Progress Printing

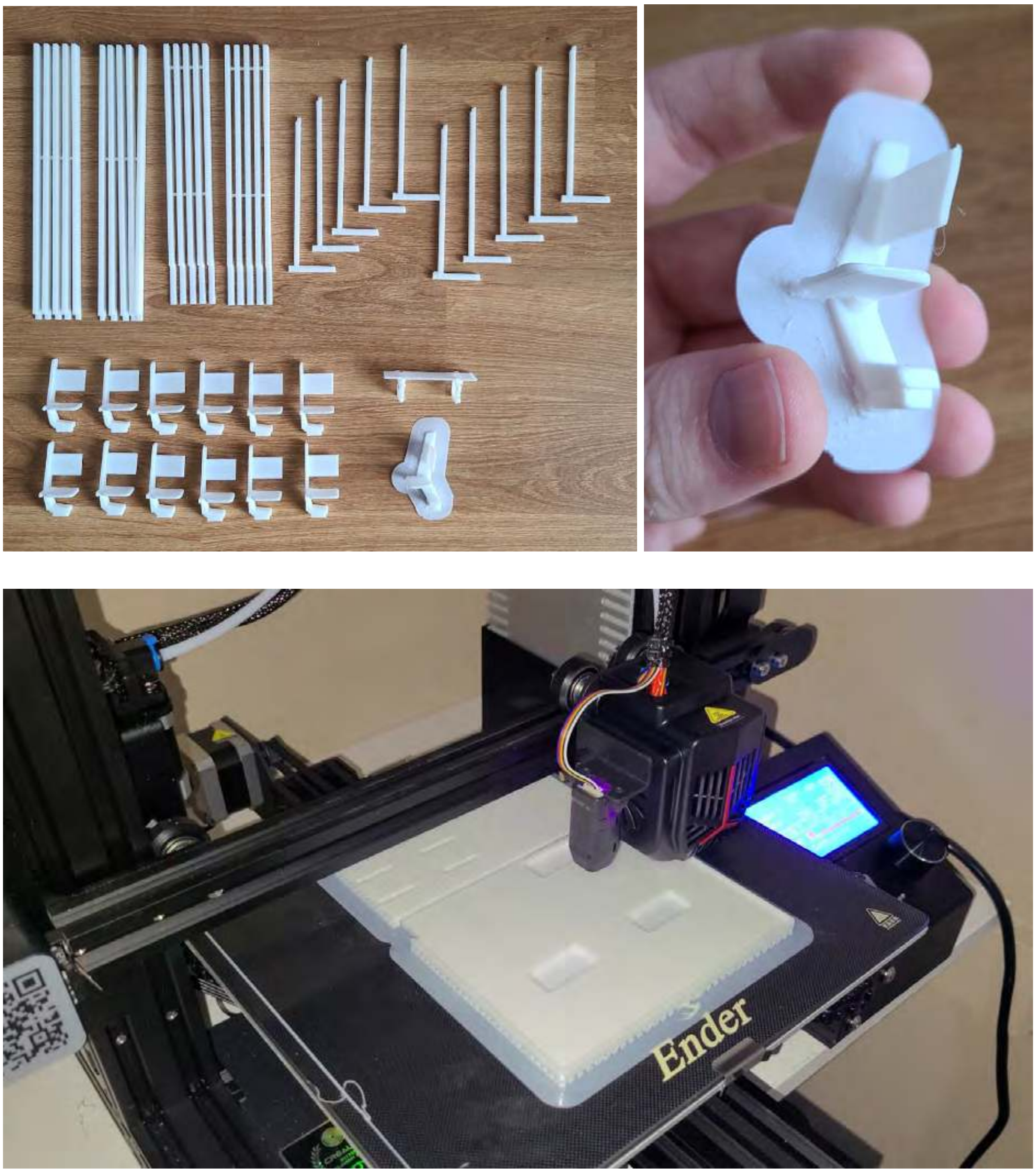


Figure 49

3D-Printed Model Preparation Including Plastic Welding and Initial Primer

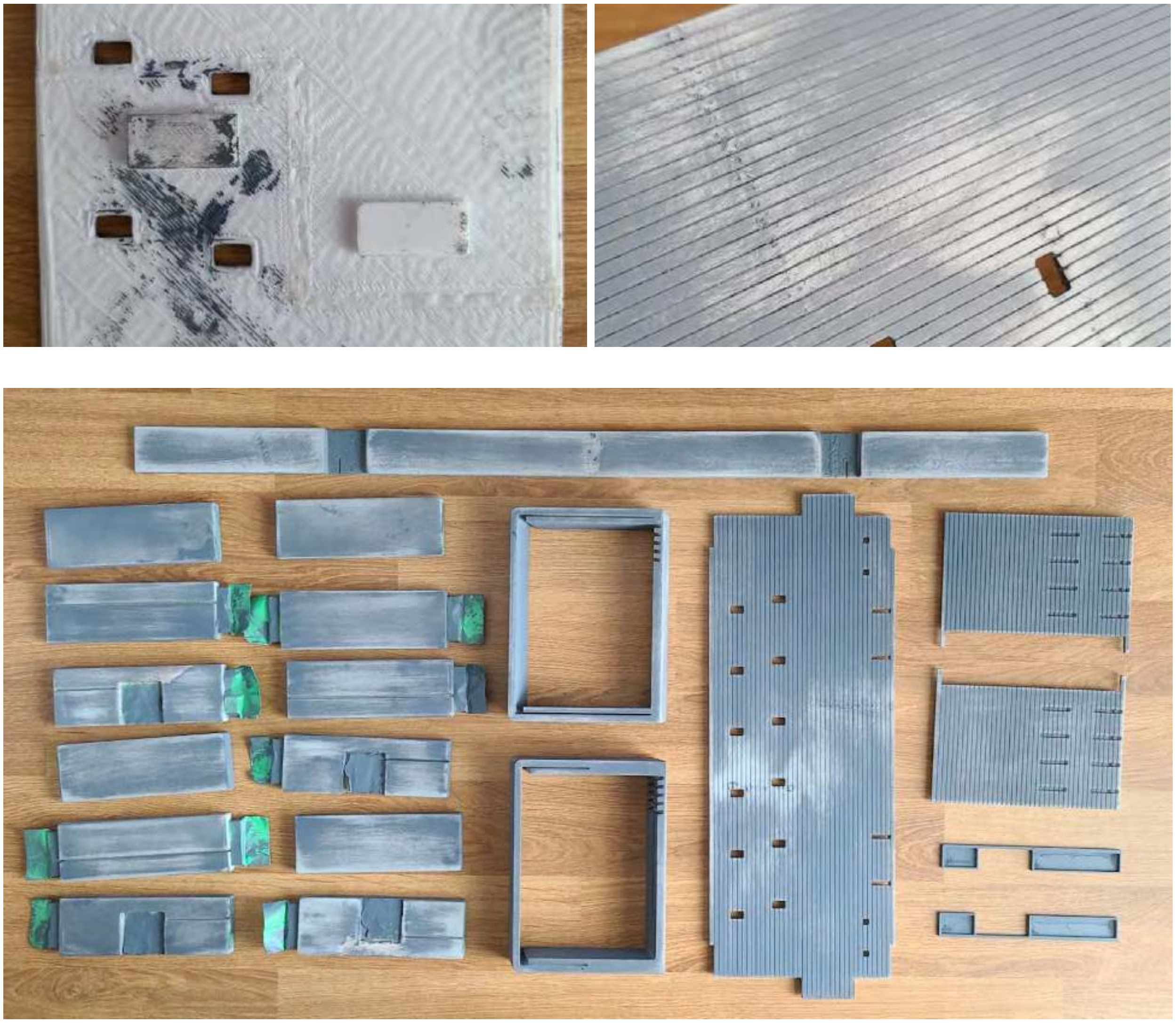


Figure 50

Laser Cut 0.04” and 0.02” Plexiglass Components To Represent Glass

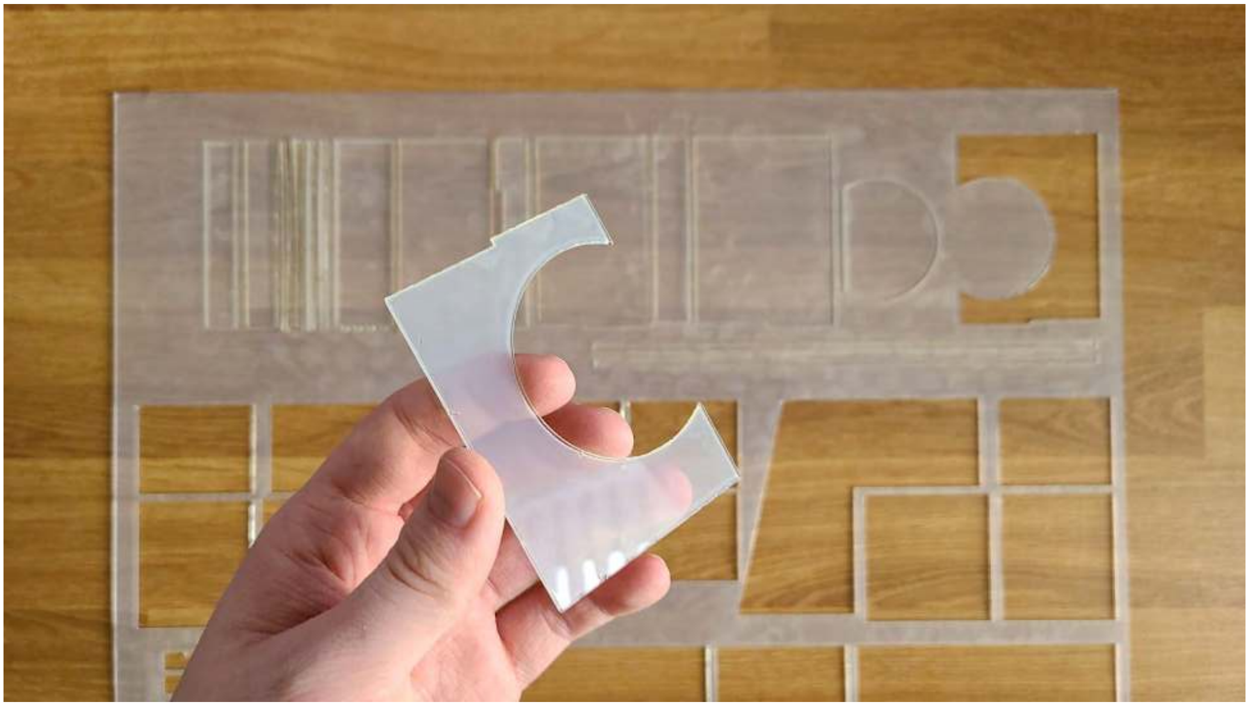


Figure 51

Sourced Materials for Miniature Garden Bed including Mulitple Plants, Moss, and Dirt

Chapter 5 - Final Design

5.1 Design Summary

Terra is a Maglev streetcar designed to re-envision the potential of public transportation with a focus on rider experience and social responsibility. Terra redesigns the public transit rider experience with a focus on privacy, visibility, and accessibility for all types of users. Choose between three styles of seats: Primary/Privacy, Elevated Counter, and Accessibility Bench. Privacy is a passive affordance for Terra riders, with barriers blocking the users' torso, creating perceived privacy. Dedicated porch environments at the front and rear of Terra store any form of micromobility vehicle including bikes, scooters, and electric options. Three entrances reduce crowding and contribute to operational efficiency.

5.2 Design Criteria Met

The final design critically satisfies all four essential pillars for design excellence:

Table 22

The Four Essential Pillars for Design Excellence

Enhancement of Human Lifestyle	Human-Interaction & User-Centric Design	Ergonomics & Human Factors Design	Sustainability & Social Responsibility
Terra is designed to improve the city experience through an innovative public transportation solution. Connect with the street environment through open-air window design, allowing fresh air and local culture to connect with riders inside the vehicle.	Terra is designed considering diverse, global transit experiences to address issues like crowding, privacy, accessibility, and availability. A hop-on hop-off experience makes Terra quick, convenient, and familiar for both local and visiting users. Enjoy a view of urban nature from any spot in the staggered privacy seating, creating a more connected sense of travel.	Terra features three styles of seating to accommodate individual preference and group requirement. Designed to be step-less, Terra is fully accessible to all users - accommodating up to four wheelchairs or strollers with safety harnesses. Both comfortable and durable, all seating is easily replaceable for regular maintenance.	Terra restructures urban transportation to prioritize sustainability at systemic, vehicle, and experience level design. Maglev technology effectively eliminates local emissions and vehicle particulates leading to clean air and clean streets.

5.2.1 Full Bodied Interaction Design

Figure 52

Furniture Schematic, 1st Percentile Female and 99th Percentile Male

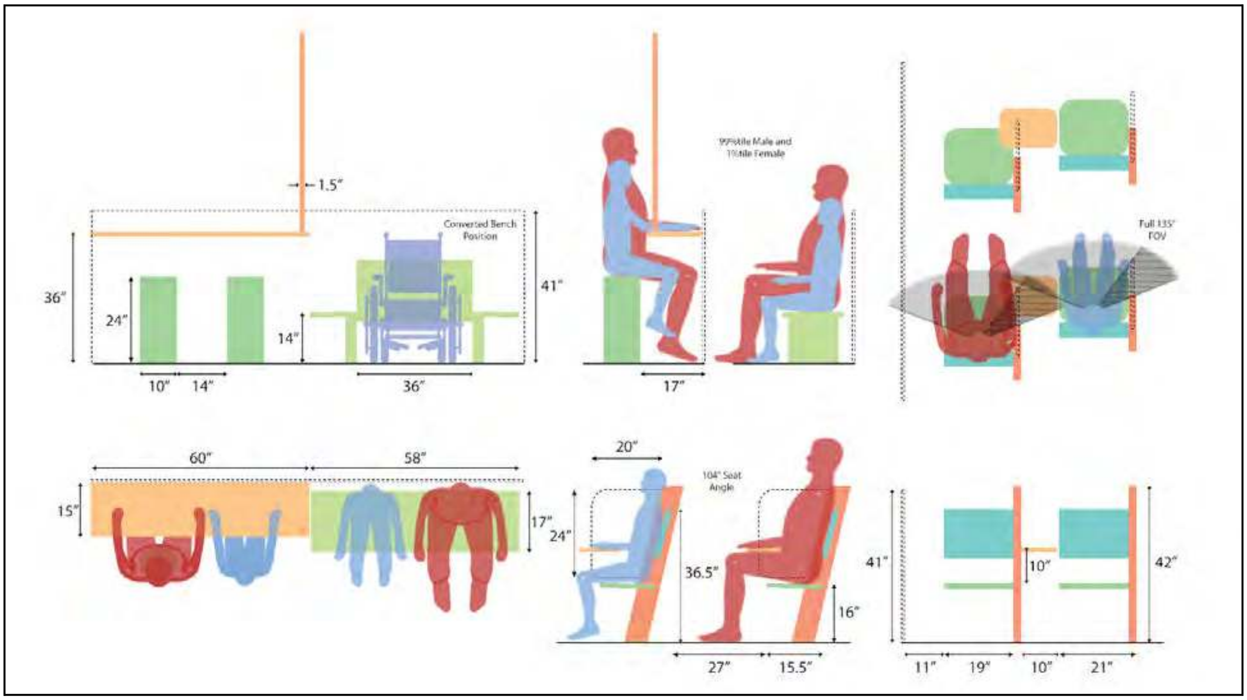


Figure 53

Floorplan Schematic

5.2.3 Design Implementation

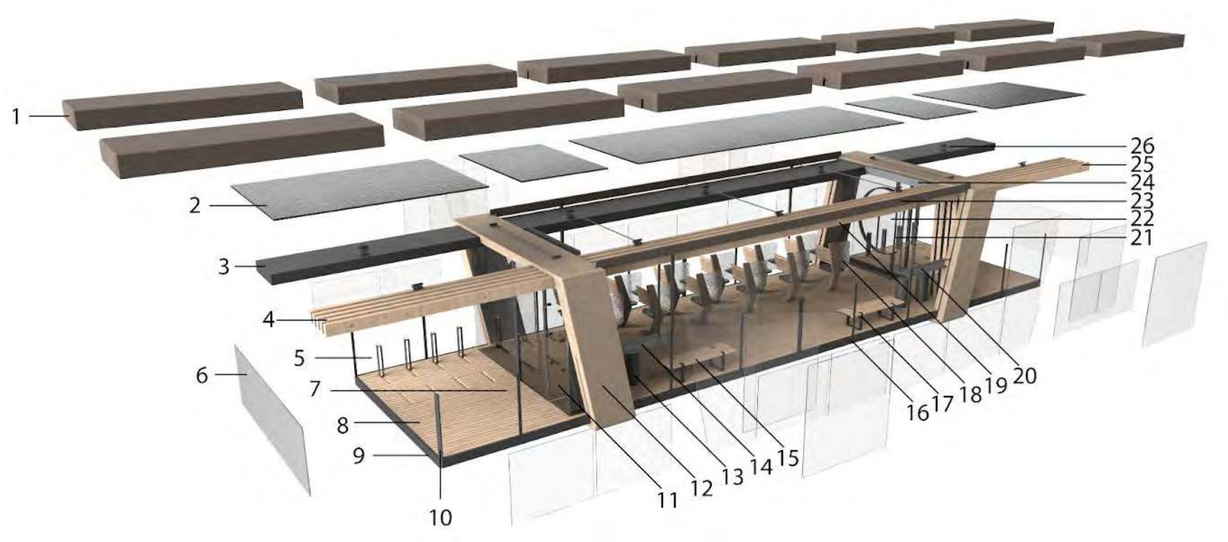


Table 23

Bill of Materials

Part #	Description	Quantity	Material	Manufacturing Method
1	Roof Panel Assembly	12	1.1 Chassis Assembly, Aluminum 1.2 Exterior Cladding, Tadelakt (custom Dark Brown)	1.1 Stamping 1.2 Tadelakt, Artisan
2	Ceiling	6	Figured Glass, Solar Control Glazing	Molding, Post Treatment
3	HVAC Housing Assembly	3	3.1 HVAC, Supplied and Assembled by OEM 3.2 Exterior Cladding, Powdercoat Aluminum	3.1 Supplied and Assembled by OEM 3.2 Stamping, Post Treatment
4	Decorative Slat	25	Rift Sawn White Oak	Rift Sawn Post Treatment, Water-based Urethane and UV coating
5	Micromobility Storage Assemblies	8, 12	5.1 Bicycle Mount 5.1.1 Spring Assembly, Supplied and Assembled by OEM 5.1.2 Support Walls, Powdercoated Galvanized Steel (6 gauge) 5.1.3 Handle, White Oak 5.2 Wall Hook Assembly, Steel, Supplied and Assembled by OEM	5.1.1 Supplied and Assembled by OEM 5.1.2 Stamping, Post Treatment 5.1.3 Milled, Post Treatment, Water-based Urethane and UV coating 5.2 Supplied and Assembled by OEM
6	Window/Door Glass	30	Tempered Glass, Solar Control Glazing	Molding, Post Treatment
7	Maglev Propulsion Assembly	1	Supplied and Assembled by OEM	Supplied and Assembled by OEM
8	Floor Board Assembly	1	Rift Sawn White Oak	Rift Sawn Post Treatment, Water-based Urethane

				and UV coating
9	Chassis Assembly	1	9.1 Chassis, Aluminum 9.2 Exterior Cladding, Powdercoat Aluminum	9.1 Stamping 9.2 Stamping, Post Treatment
10	Window/Door Trim	28	10.1 Chassis, Aluminum 10.2 Exterior Cladding, Powdercoat Aluminum	10.1 Stamping 10.2 Stamping, Post Treatment
11	Garden Bed + Wall Assembly	2	11.1 Walls/Door, Tempered Glass 11.2 Garden Bed 11.2.1 Chassis, Aluminum 11.2.2 Exterior Cladding, Powdercoat Aluminum 11.3 Door Rails, Supplied and Assembled by OEM	11.1 Molding, Post Treatment 11.2.1 Stamping 11.2.2 Stamping, Post Treatment 11.3 Supplied and Assembled by OEM
12	Arch Assembly	2	12.1 Chassis, Aluminum 12.2 Exterior Cladding, Tadelakt (custom Light Taupe)	12.1 Stamping 12.2 Tadelakt, Artisan
13	Stool Assembly	4	13.1 Stool Seat, Black Ceramic 13.2 Stool Base, Black Ceramic 13.3 Fastener Bracket Assembly, Steel	13.1 Molding, Post Treatment 13.2 Molding, Post Treatment 13.4 Supplied and Assembled by OEM
14	Counter Assembly	2	14.1 Counter Top, Black Ceramic 14.2 Fastener Bracket Assembly, Steel	14.1 Molding, Post Treatment 14.2 Supplied and Assembled by OEM
15	Accessible Bench Assembly	2	15.1 Bench Seat, Rift Sawn White Oak 15.2 Bench support assembly, Powdercoated Galvanized Steel (6 gauge) 15.3 Locking Hinge, Supplied and Assembled by OEM 15.4 Fasteners, Powdercoat Steel	15.1 Rift Sawn Post Treatment, Water-based Urethane and UV coating 15.2 Stamping 15.3 Supplied and Assembled by OEM 15.4 Supplied and Assembled by OEM
16	LED Ambient Interior Light Strip	6	Supplied and Assembled by OEM	Supplied and Assembled by OEM
17	Accessible Seatbelt Assembly	8	17.1 Housing Assembly, Powdercoat Steel 17.2 Seatbelt Assembly, Supplied and Assembled by OEM 17.3 Fasteners, Powdercoat Steel	17.1 Stamping, Post Treatment 17.2 Supplied and Assembled by OEM 17.3 Supplied and Assembled by OEM
18	Privacy Seat Assembly	12	18.1 Chassis, Aluminum 18.2 Exterior Cladding, Tadelakt (custom Light Taupe) 18.3 Privacy Barrier, Figured Glass, Solar Control Glazing 18.4 Seat, Black Ceramic 18.5 Seat Support, Vulcanized Rubber 18.6 Bracket Assembly, Steel 18.7 Fasteners, Powdercoat Steel	18.1 Stamping 18.2 Tadelakt, Artisan 18.3 Molding, Post Treatment 18.4 Molding, Post Treatment 18.5 Molding 18.6 Supplied and Assembled by OEM 18.7 Supplied and Assembled by OEM
19	LED Overhead Interior/Exterior Light Panel	15	Supplied and Assembled by OEM	Supplied and Assembled by OEM
20	Window/Door Seal Assembly	12	20.1 Weather Seal, Clear Vinyl 20.2 Bracket, Powdercoat Aluminum	20.1 Extrusion 20.2 Extrusion

21	1.5” Handrail	4	Powdercoat Aluminum	Extrusion
22	Interactive Navigation Screen Assembly	2	22.1 In-Glass Screen, Supplied and Assembled by OEM 22.2 Screen Trim, Powdercoat Aluminum	22.1 Supplied and Assembled by OEM 22.2 Stamping
23	Window/Door Motor Assembly	6	Supplied and Assembled by OEM	Supplied and Assembled by OEM
24	Transit Map Screen Assembly	2	Supplied and Assembled by OEM	Supplied and Assembled by OEM
25	Slat Support Assembly	6	25.1 Pika Screw 25.2 Rod Assembly, Stainless Steel	Supplied and Assembled by OEM
26	Glass Ceiling Support Assembly	10	26.1 Bracket, Powdercoat Steel 26.2 Rubber Seal	26.1 Stamping 26.2 Molding

5.3 Final CAD Rendering

Figure 54

Terra, Maglev Streetcar Insitu 1

Figure 55

Terra, Maglev Streetcar Insitu 2

Figure 56

Mircomobility Storage Porch

Figure 57

Floorplan Ingress and Egress

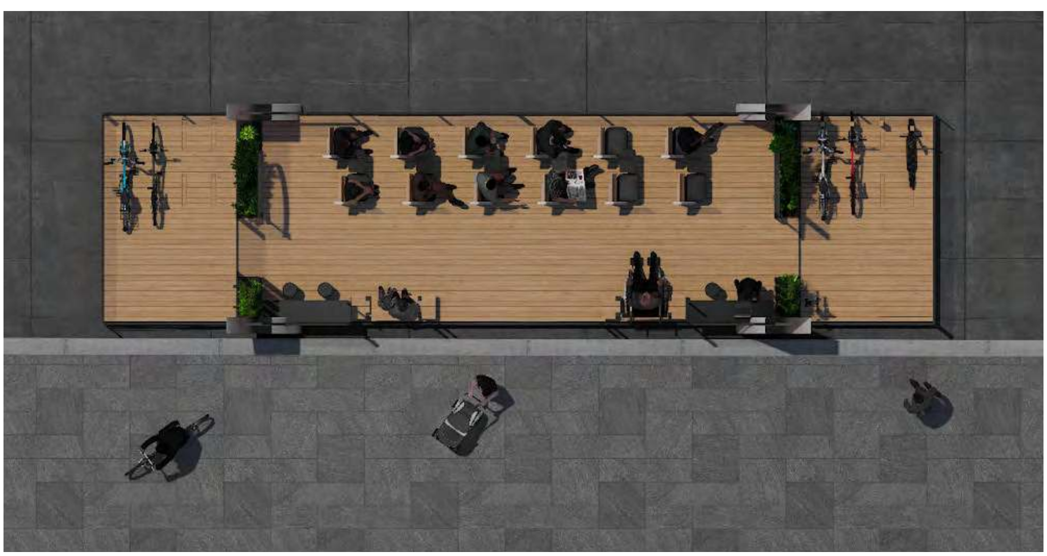


Figure 58

Interior Cabin, In use

Figure 59

Exterior Insitu View, Night Lighting

5.4 Physical Model

Unfortunately, due to a poorly timed COVID-19 infection - the final model portion of this assignment was not able to be completed by the submission date of this report. This section will cover the pre-completion final model of Terra, Maglev Streetcar.

The model is made from primarily 3D-printed PLA and laser-cut plexiglass. Using a combination of spray painting and hand painting techniques the model is able to accurately represent the final design in physical form. Additional details include scale plant beds using several types of sourced miniature diorama materials. The completed version of this model is showcased alongside the final banner visual presentation and a physical copy of this design dossier at the 2023 Humber Industrial Design Thesis Show.

Figure 60

Physical Model, Dry Fit Assembly

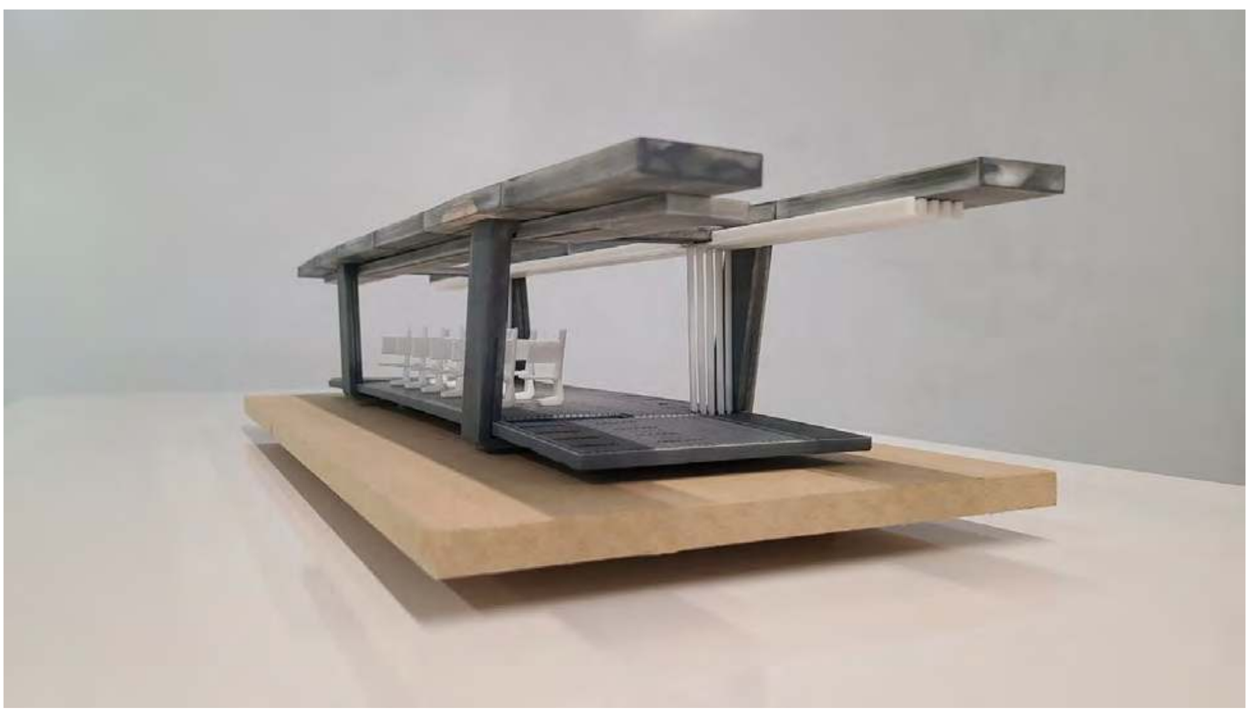


Figure 61

Physical Model, Dry Fit Assembly 2

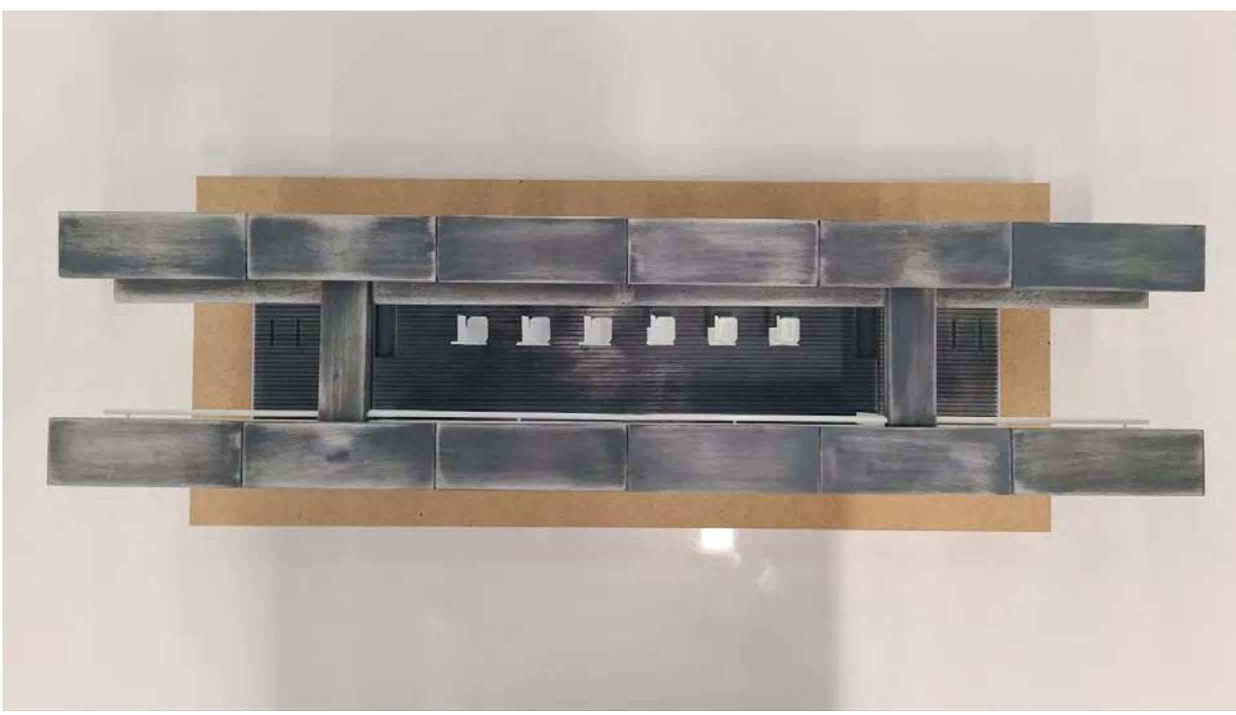
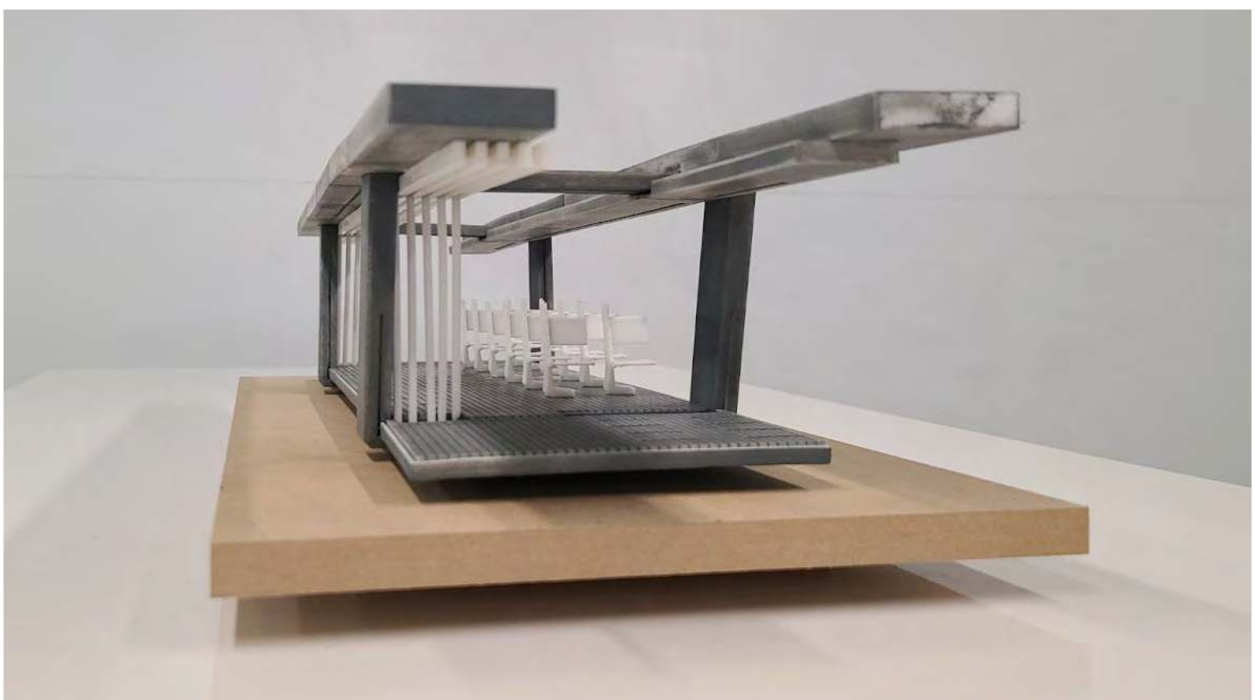


Figure 62

Physical Model, Dry Fit Assembly 3



5.5 Technical Drawing

Figure 63

Vehicle Dimensions, 1:75 Scale

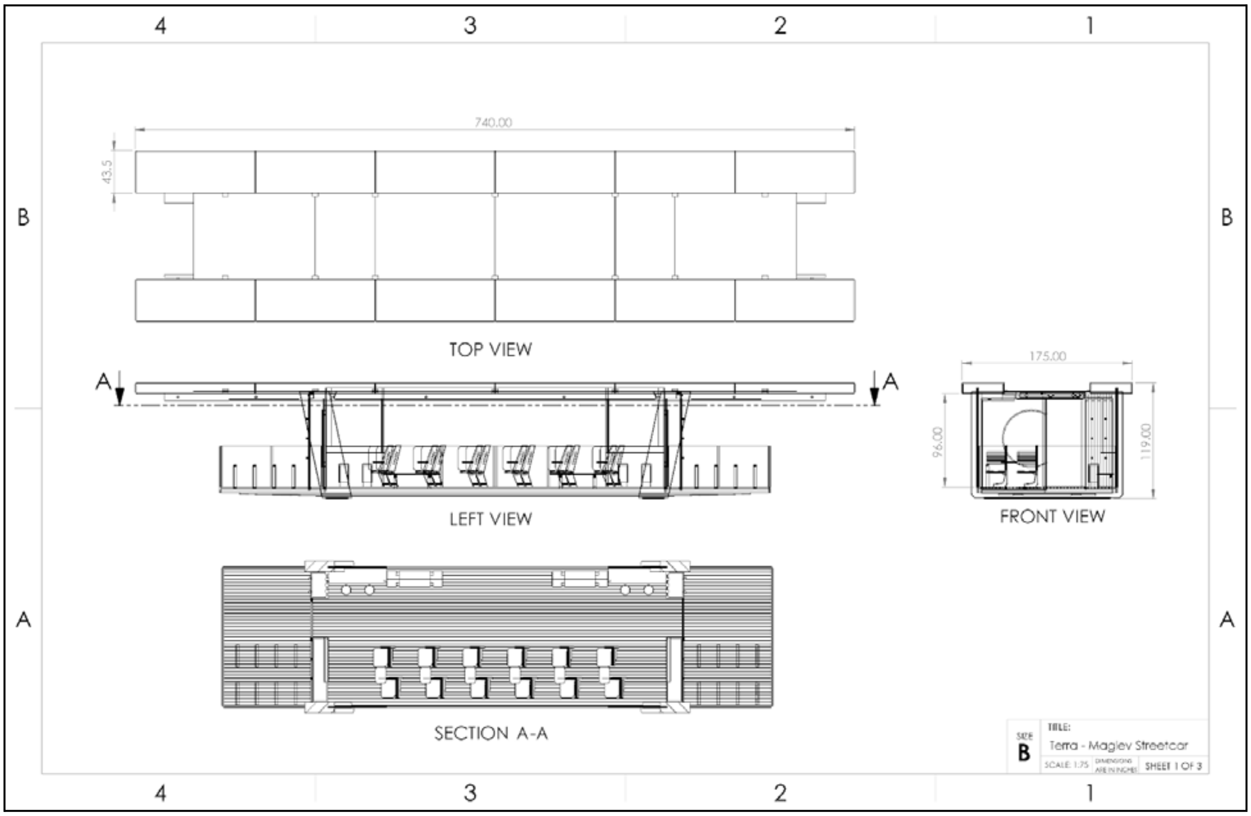


Figure 64

Vehicle Floorplan, 1:50 Scale

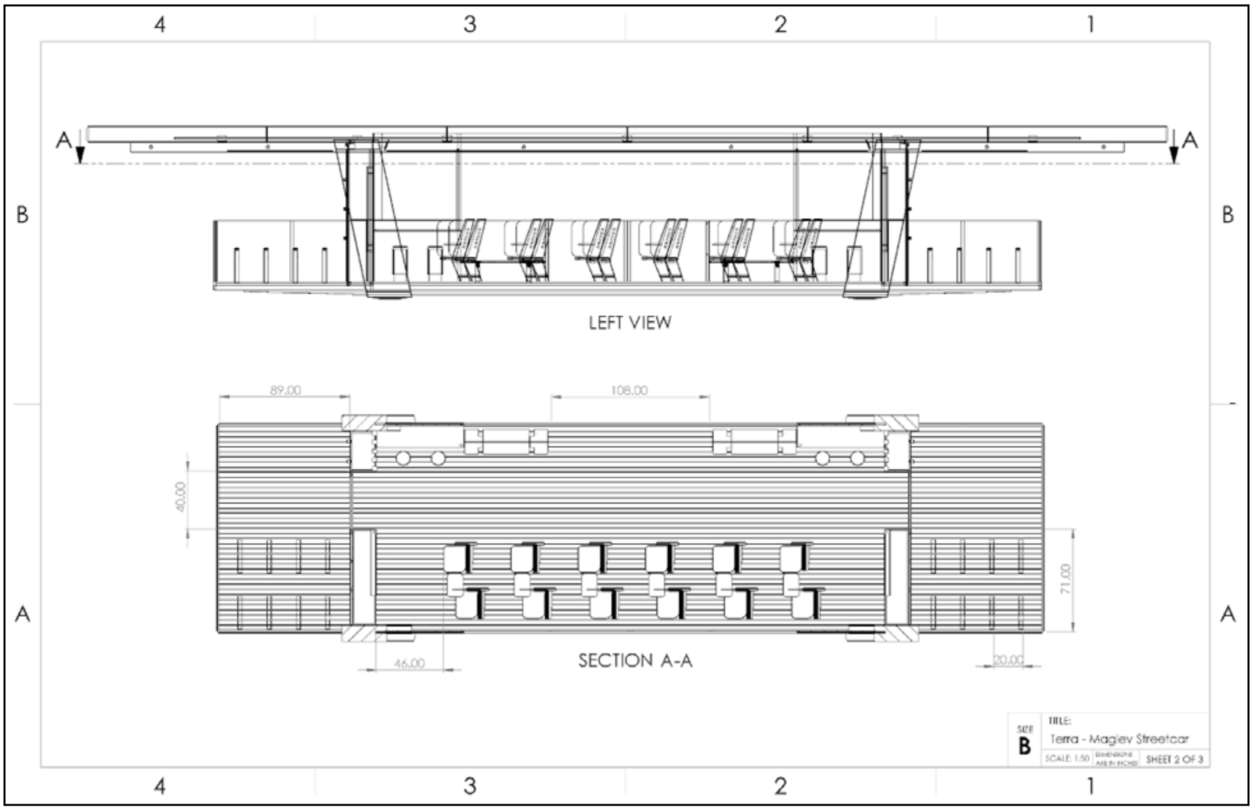
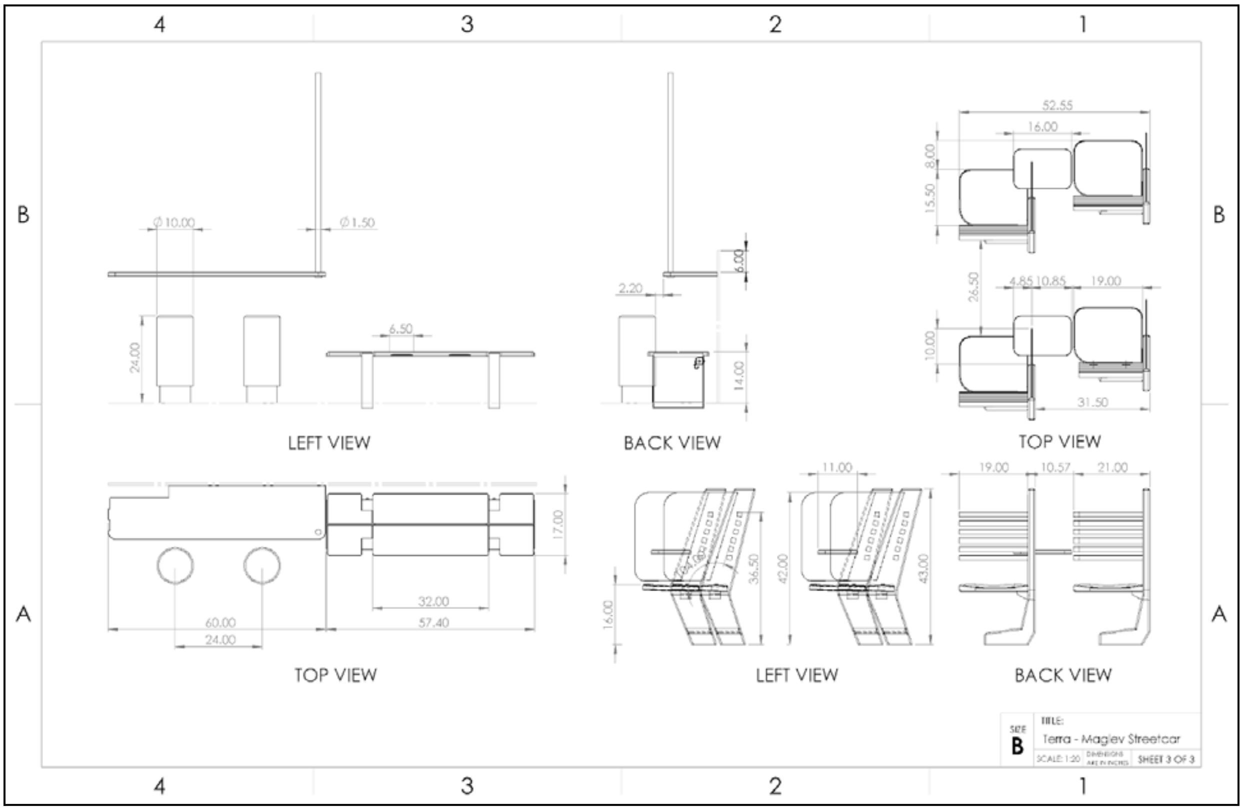


Figure 65

Furniture Dimensions, 1:20 Scale



5.6 Sustainability

Terra is committed to providing a vision of a cleaner future for city transportation. Substantial sustainability efforts include system-level efficiency, propulsion and fuel sources, material composition, and a redefined user connection to urban green space. This project aimed to create a win-win-win scenario environmentally, economically, and socially. Additionally, it needed to satisfy the definition of sustainability per Sultana et al. (2017): “Meets the needs of the present without compromising the ability of future generations to meet their own needs”. Ultimately, Terra successfully balances the project sustainability goals for a public transportation vehicle, in the year 2050.

Chapter 6 - Final Design

This project aimed to create a vision of public transportation for the year 2050 in Southeast Asia. Terra is a Maglev Streetcar designed to replace the use of privately owned cars in large cities. This design is a sustainable initiative for transportation innovation with a focus on improving the daily lifestyle of a commuter in the city. By applying user insights and understanding legacy solutions a unique opportunity to innovate led to this final design. The following Figures 54 and 58 on page 121 are a review from section 5.3 of the final thesis design.

Figure 54, *Review*

Terra, Maglev Streetcar Insitu 2

Figure 58, *Review*

Interior Cabin, In use

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Appendix

IDSN 4002

Humber ITAL / Faculty of Applied Sciences & Technology

Bachelor of Industrial Design / FALL 2022

SENIOR LEVEL THESIS ONE

Catherine Chong / Frederic Matovu

THESIS TOPIC APPROVAL:

Student Name:	Thomas Purchase
Topic Title:	How may we revolutionize urban transportation in a new city?

TOPIC DESCRIPTIVE SUMMARY (PRELIMINARY ABSTRACT)

According to authors of the Proceedings of the National Academy of Sciences, within 50 years, regions of Earth's temperature will rise to uninhabitable levels affecting 30% of the projected human population. This thesis proposes a revolutionary transportation vision for the new megacities these billions of climate migrants may build. The conception of new cities in undeveloped parts of the world, less affected by climate change, creates an opportunity for innovative transportation design not constrained by existing infrastructure. The design will improve user lives in an urban environment by focusing on revolutionary experience change.

Primary research methods may include interviews and user observation studies to understand behaviour, accessibility needs, and ergonomic factors. A full-scale ergonomic study will be done to test various elements of human interaction and user comfort. Additionally, existing models can be used to score the system's sustainable factors environmentally, economically, and socially. The research results will inform an impactful industrial design solution with user-based data.

This proposal asks how revolutionary public transportation can be designed for new major cities, as a response to climate change migration.

Student Signature(s):	
Date:	06 / 10 / 2022

Instructor Signature(s):	
Date:	07 October 2022

IDSN 4502
SENIOR LEVEL THESIS TWO

Humber ITAL / Faculty of Applied Sciences & Technology
Bachelor of Industrial Design / WINTER 2023
Catherine Chong / Fredric Matovu

CRITICAL MILESTONES: APPROVAL FOR CAD DEVELOPMENT & MODEL FABRICATION

Student Name:	Thomas Purchase
Approved Thesis Title:	Rethinking Urban Transportation

THESIS PROJECT – DESIGN APPROVAL FORM

Design is reviewed and approved to proceed for the following:	[X] **CAD Design and Development Phase**
Comment:	Continue design refinement in CAD development, need to iron out detailing and product's features, pay attention to surfacing, components and assembly methods for design feasibility. Viable holistic design thinking in conjunction with considerations into sustainability aspects. CAD development must be at least 75% complete for review before approval for fabrication.

Design is reviewed and approved to proceed for the following:	[X] **Model Fabrication Including Rapid Prototyping / 3D Printing and Model Building Phase**
Comment:	Waiting for CAD development review (as of Feb-21). Good progress with CAD, design completed, continue detail refinement, once refined, fabrication of model can begin.

Instructor Signature(s):	Catherine Chong F.K. Matovu
Date:	07 March 2023

PANEL ON
RESEARCH ETHICS
Navigating the ethics of human research

TCPS 2: CORE 2022

Certificate of Completion

This document certifies that

Thomas Purchase

successfully completed the Course on Research Ethics based on the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans (TCPS 2: CORE 2022)

Certificate # 0000862848

1 October, 2022