The BikePack Buddy: A Solution to Back Pain from Wearing Backpacks While Riding On Toronto Bike Share Bicycles

Design Report

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1. Introduction

In this design report, we present a recommended design to solve an identified splartz: something that does not greatly impact day-to-day life but can be improved. The splartz we chose concerns back pain caused by biking while wearing a backpack, specifically with the Toronto Bike Share **(TBS)** bikes. The back pain is not caused by the TBS bikes themselves, but rather due to the user having to wear their backpack while riding, since there is nowhere to attach the bag. Additionally, research shows that when the spine is flexed forward in a cycling posture, the spine experiences substantially greater backpack related loads than during upright walking, further exposing the user to back pain [1].

While TBS bikes already have a front basket, it is not large enough to fit large backpacks as seen in Figure 1. In addition, although bike rack attachments currently exist, they are either designed as permanent attachments or are not easily portable, as seen in Figure 2.

Figure 1: Backpack not fitting in the front basket.

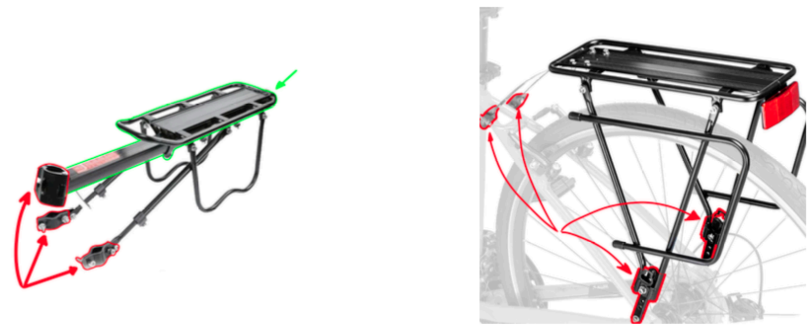


Figure 2: An example of two reference designs, one being collapsible (left) and the other being fixed. Both have permanent attachments.

Thus, this document recommends a frontal bike attachment to the bike's basket on which a backpack can be secured. The report will describe the opportunity, the objectives and requirements framework, the recommended design, other candidate designs, and testing and comparison procedures that led to the recommendation.

2. The Toronto Bike Share System and Biking with Backpacks

Since 2011, the TBS program has been in effect, allowing people to rent bikes for short periods of time as a means of transportation throughout the city [2]. In order to participate in the program, one must purchase a pass on the app with their phone, scan the QR code on a bike at a station, ride to their destination, and then simply push the bike into the destination dock (refer to Figure 3). Although this system has proved to be convenient and useful, it is challenging to bike around with one's belongings without wearing a backpack.

Step 1: Scan the QR code Step 2: Ride to your destination Step 3: Dock it at a station

Figure 3: Tangerine bike usage

After interviewing several Engineering Science students, many claim they ride to school using TBS bikes [3]. In order to bring their textbooks and devices with them, several choose to wear backpacks to store their belongings as they operate the bicycle. Although this frees up their hands, studies show that backpack usage produces stress on the lower back, causing back pain proportional to the backpack's weight [4]. Here, the team saw an opportunity for a design that would solve this need. A successful design would allow Engineering Science students to commute using TBS bikes while wearing a backpack without experiencing loads to their lower back.

3. Stakeholders

In order to effectively create a design, one must first consider the stakeholders who will be affected by it. In our case, the stakeholders could be broken down into three categories: Primary, Secondary, and Tertiary. The identified stakeholders and their interests are described in the table below.

Type	**Stakeholder**	**Interests**
Primary	Praxis I and Engineering Science Students	Want their bags to be transported with them without back pain and with no impact to their biking experience.
Secondary	Toronto Drivers	Do not want to be disturbed by users of the design.
Secondary	Other TBS users	Do not want to be disturbed by users of the design.
Tertiary	Government of Ontario	Wants to ensure that any attachment to a mode of transportation respects the safety and road laws currently in place [5].
Tertiary	TBS	Wants to prevent permanent alterations to the usability of their bikes [6].

4. Requirements and Evaluation Criteria

Considering the back pain caused by backpacks, as well as the hop-on, hop-off nature of the TBS Bikes, the need for our opportunity was determined to be a portable system that allows the user to ride a bicycle with a backpack without taking load to their back. This led the team to develop a set of requirements and evaluation criteria listed below to determine which designs outperformed others. Evaluation criteria that are underlined are given more weight in the convergence process.

Requirement	Metric	Evaluation criteria
4.1 Must fit in a standard backpack	Dimensions (cm) Mass (kg)	The closer it is to laptop dimensions and mass, the better. MacBook size: (width x height x length) (36cm x 25cm x 2cm) MacBBook weight: 2.15 kg [7]
Justification: The device must be portable to meet the stakeholders' needs. To achieve this, the device must fit in a standard backpack. We chose the best shape to be that of a laptop, because most backpacks already provide a space for storing laptops, thus we ensure the device would be efficiently stored in most backpacks.		
4.2 Cannot cause permanent deformations to objects inside the backpack or to the backpack itself	Force (N)	The less force required to secure the backpack to the device, the better.
Justification: The device shall not apply too much force so as to ensure objects inside the backpack are not deformed. It is also necessary that the backpack is not permanently damaged after using the device.		
4.3 Must hold bag securely	Acceleration (m/s^2) Angular speed (rad/s)	The less translational and rotational vibration during use, the better.
Justification: If the vibrations of the device are minimized, objects inside the bike will be less likely to break or deform. This evaluation criterion will measure how well the connection between the bike and the device is achieved through both attachment and with extra forces applied [8].		

4.4 Must require fewer than 20 steps to use	N. of steps	The fewer steps, the better
Justification: To meet the goal of rapid attachment, the number of steps cannot exceed 20, as decided by the stakeholders, and the fewer the steps needed, the better [9].		
4.5 Must have fewer than 30 different parts	N. of parts	The fewer parts, the better
Justification: A complicated design would mean that more parts can fail, making it more complicated to repair and maintain [10].		
4.6 Follows all relevant road and safety regulations	N/A	The design must follow the law
Justification: According to the *Ontario Highway Safety Act*, a bicycle is considered a vehicle with all the same responsibilities and requirements as a motorized vehicle. Therefore, any design cannot impede the rider's ability to fulfill all provincial safety laws [5].		
4.7 Does not cause visible damage to the TBS bikes	Number of scratches and dents	There cannot be any visible damage on the bike, for example, scratches or dents.
Justification: The design cannot cause any visible damage to the TBS bikes in accordance with the user agreement, as the user is liable for all damage caused to the bike during their period of use [6].		
4.8 Does not significantly raise the center of mass of the bike	Distance (cm)	The lower the center of mass of the device, the better.
Justification: The moment of inertia is calculated using the center of mass of the overall system. By reducing the height of the center of mass, the stability of the bike is greatly improved, as seen in Appendix C [11].		

5. Recommended Design - Front Basket Extension

The chosen design consists of a front basket extension that would be mounted on the basket at the front of the bike, as shown in Figure 4. When transported, the device would fold into itself to dimensions similar to those of a laptop. The design's shape is shown in Figure 5. A demonstration can be seen in this video.

Figure 4: Design 1 prototype mounted on bike

Figure 5: 3D model of Design 1

While other designs do provide valuable advantages, such as improving weight distribution along the length of the bike for better braking, the recommended design provides a balance of weight, stability, and compactness that provides the most utility to Praxis students trying to commute by bike.

However, we qualify that this recommendation is limited by your lack of experience to judge the accuracy of how we predict a design may operate. While we created prototypes, researched reference designs, and ran proxy tests for parts of the design we were unclear about, we made implicit assumptions throughout the design process. Even within our evaluation criteria, there were aspects we could not fully account for, such as the specifics of bag deformation due to the different degrees of freedom the objects in the bag may have.

6. Divergence

In the early ideation stage of our design, we made use of multiple diverging techniques. As seen in Figure 6, we used a morph chart to find all the possible permutations between the various solutions for each component. This helped us better visualize distinct solutions we thought best fit our evaluation criteria.

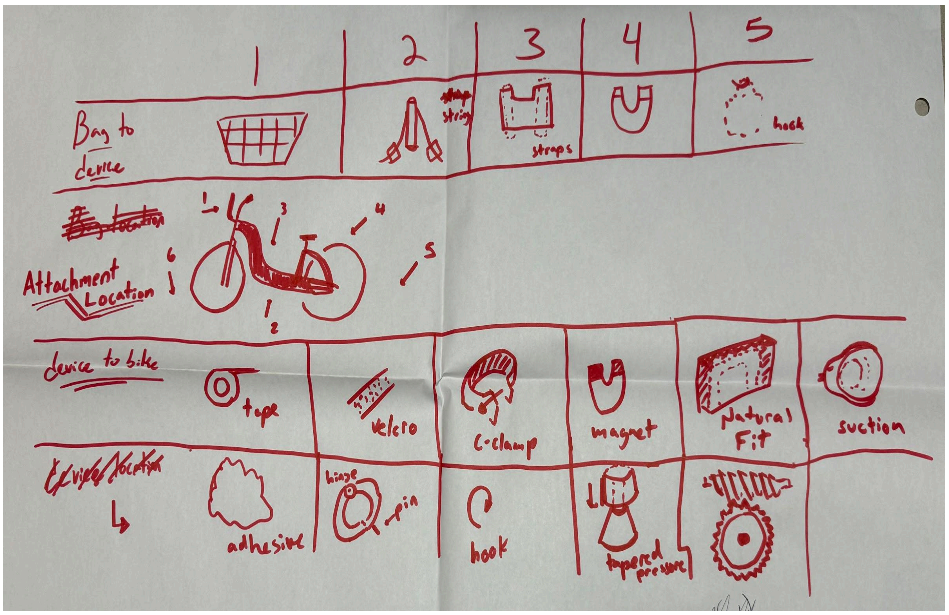


Figure 6: View of morph chart made in studio.

Alongside the morph chart, we used brainwriting to silently write different ideas individually in order to build upon initial ideas and prevent groupthink. Simultaneously, some of our designs used the technique of biomimicry. In our case, we used suction cups, like those of octopi, to strengthen the connection between the design and the bike. Finally, we applied the SCAMPER process to further iterate and combine our designs (Appendix F). After a convergence process based on our set requirements and criteria, we were left with five candidate designs suitable for further consideration.

7. Candidate Designs

In this section we will present 5 candidate designs that stood out in the convergence process. CAD models for 4 of them are shown in Appendix B.

7.1 Candidate Design 1: Front Basket

As seen in Figure 7, we created a design which would attach to the existing front basket of the bike. One would attach the backpack to the design with buckle straps and the elastic band that currently exists on the bike.

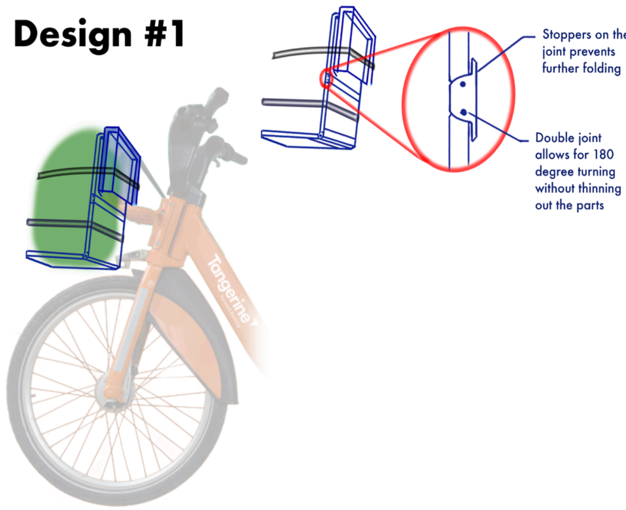


Figure 7: Candidate design #1. A platform for the backpack attached to the front basket.

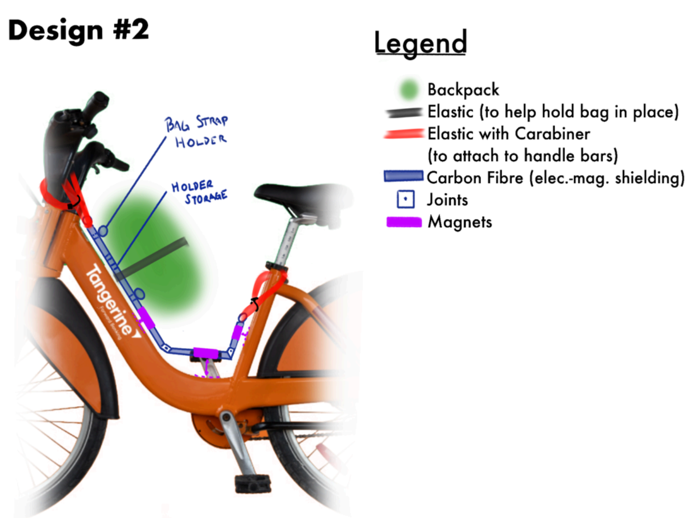


Figure 8: Candidate design #2. An electromagnetic suspension attached to the bike with three elastic straps.

7.2 Candidate Design 2: Electromagnetic Suspension

As seen in Figure 8, we created a design which would support the backpack through electromagnetic induced repulsion. One would wrap elastics around the handlebars and the seat post to ensure alignment of the device with the bike and attach the backpack to the device with a strap.

7.3 Candidate Design 3: Back Axle Trailer

As seen in Figure 9, we created a design which would transport the backpack separately from the bike. One would attach the device to the bike with two clamps on the back axle, and the bike would pull the device as the user rides.

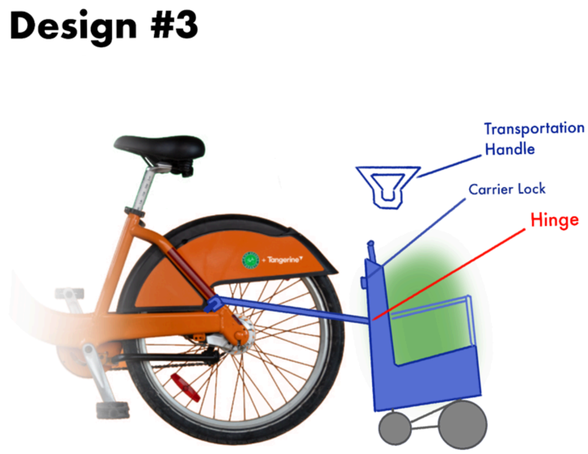


Figure 9: Back axle trailer design

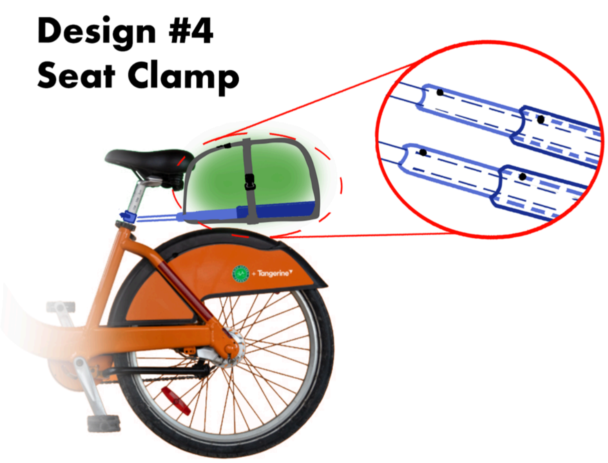


Figure 10: Candidate design #4. A platform for the backpack clamped onto the seat post.

7.4 Candidate Design 4: Seat Clamp Cantilever

As seen in Figure 10, this design consists of an attachment to the seat post, which would extend behind the user as they ride, where the backpack would be secured. This allows for quick attachment to only one point with increased portability, with a tradeoff for poor stability (see section 9).

7.5 Candidate Design 5: Truss

As seen in Figure 11, this design consists of an attachment to the seat post, similar to Candidate Design 4, but also to the bottom frame of the bike. The differentiating factor from Candidate Design 4 would be the extra attachment point, which provides greater stability but worsens ease of attachment.

Figure 11: Candidate design #5. A platform for the backpack clamped onto the seat post and bike frame.

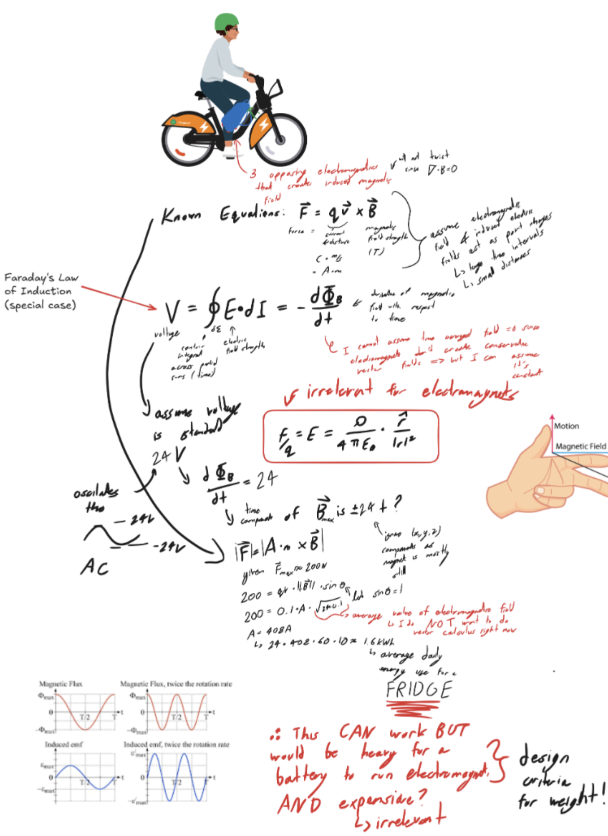


Figure 12: Design 2 prototype calculations.

8. Calculations

While our mechanical design for Candidate Design 2 was correct, we had not fully accounted for the magnetic field strength given by the magnets with a set energy output. Thus, we used simplified versions of Maxwell's equations to calculate the energy needed to power the magnets such that they can levitate the design above the bike, as seen in Figure 12 [12].

We found that this candidate design is not feasible, as it requires too much energy to be stored in a reasonably-sized battery. Our calculations found that the energy needed to power the electromagnet for 10 minutes was about 1.6 kWh. Given that this is equivalent to the average daily electricity usage of a household refrigerator, this design would require a battery heavier than any other candidate design's self-weight [13].

Additionally, we calculated mass and dimensions using detailed CAD models for each candidate design; the results can be seen in the measurement matrix (Figure 15, Section 10). Views of the various CAD models can be seen in Appendix B.

9. Testing Acceleration and Angular Velocity

In order to better differentiate between our candidate designs, we collected data on key characteristics of each of them with the use of a gyroscope and an accelerometer. The measurement of stability and deformability was modelled by two tests: the former modelled by rotational speed as a function of time, and the latter by vertical acceleration as a function of time.

The tests were conducted by attaching a device to collect data at the approximate positions where the backpack would be situated in each design, as seen in Appendix D. The testing environment was a sidewalk with bumps in it and a curb off of which the bike would be ridden off to model a large speed bump. Due to the conditions being identical in each trial, it was determined that one trial per design position was sufficient. For each trial, the bike was ridden at a measured velocity of 5 $\pm$ 1 km/h. The results from the gyroscope testing can be seen in Figure 13, and the results from the accelerometer testing can be seen in Figure 14. All raw data was processed and plotted with MATLAB.

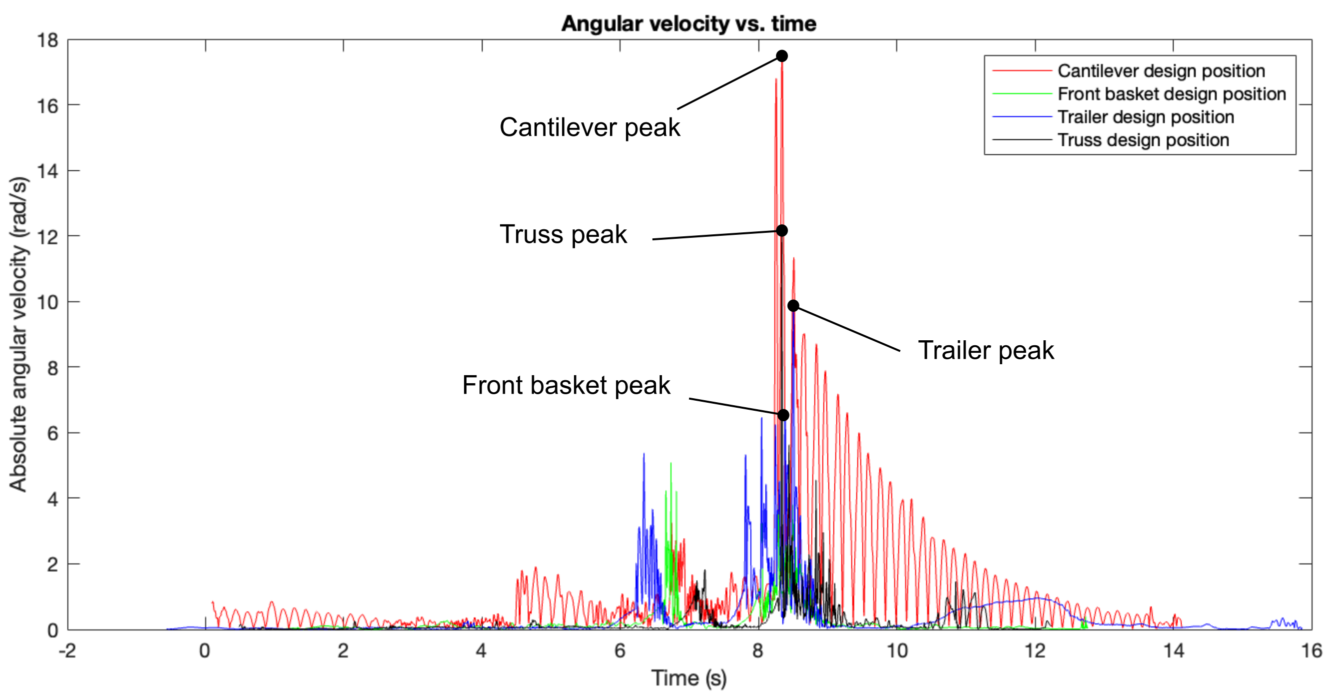


Figure 13: Attaching a gyroscope to approximate design position as the bike goes over two speed bumps.

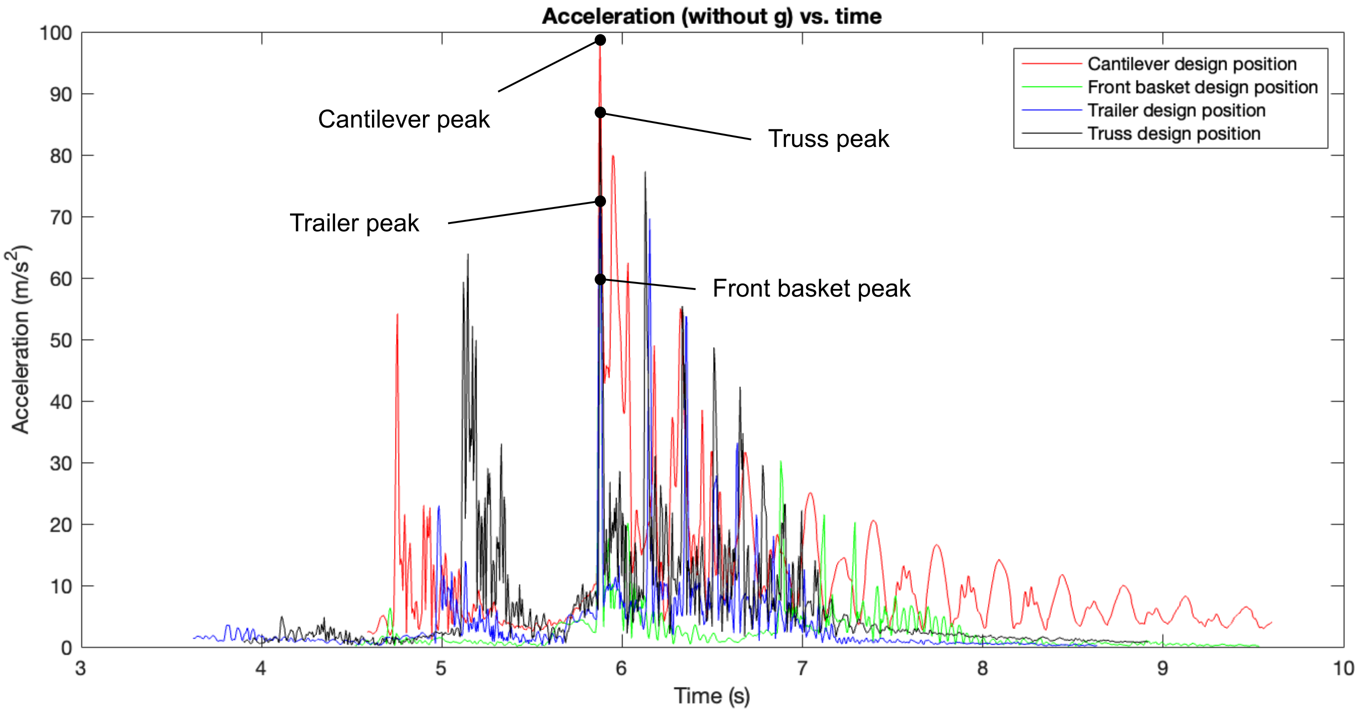


Figure 14: Attaching an accelerometer to approximate design positions as the bike goes over two speed bumps.

10. Design Decisions

For the convergence to our final design, we made use of a measurement matrix (Figure 15) and four Pugh charts based on our calculations, testing and evaluation criteria (see Appendix E). They allowed us to better understand how each design performed quantitatively relative to the others.

As shown in the Pugh Chart with the Front Basket design as the reference design (Figure 16), the only criteria where it is outperformed are in mass, number of steps, and number of parts. However, as it ultimately provides the greatest utility in the critical metrics of Size, Angular Speed, and Acceleration, we deemed the Front Basket design to be the most useful for the selected stakeholders.

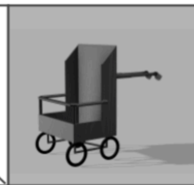
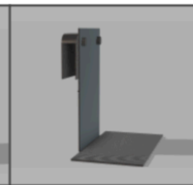
Designs / Metrics				
Size (Storage) (W x H x L in cm)	45.0 x 72.0 x 40.0	22.6 x 15.3 x 6.6	35.9 x 4.85 x 80.9	35.9 x 3.00 x 80.9
Mass (kg)	3.66	1.60	1.01	0.714
Acceleration (m / s^2)	72.6	58.7	87.2	97.4
Angular Speed (rad / s)	9.8	6.7	12.2	17.6
Number of Steps in Set-Up (#)	8	8	11	5
Number of Parts (#)	12	6	9	3

Figure 15: Measurement Matrix.

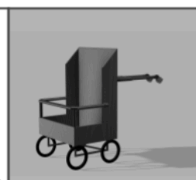
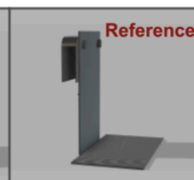
Designs / Metrics				
Size (Storage) (W x H x L in cm)	-	=	-	-
Mass (kg)	-	=	+	+
Acceleration (m / s^2)	-	=	-	-
Angular Speed (rad / s)	-	=	-	-
Number of Steps in Set-Up (#)	=	=	-	+
Number of Parts (#)	-	=	-	+

Figure 16: Pugh chart with the Front Basket as reference design.

11. Conclusion

Ultimately, our recommended design is the front basket extension, as it provides the lowest self-weight, volume, angular momentum, and acceleration experienced by the backpack among our candidate designs. Additionally, we found that it takes advantage of the elastics already present on the front of the bike. While the other designs had some advantages, they either required too much power or simply were not as convenient for the user.

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Appendix A: Design Brief

Contents

1 Introduction

Biking can be hard, so why make it harder than it already is? In this design brief, we will outline our selected opportunity of discomfort people experience from wearing their backpack while biking. We will also provide guidelines for what qualities a potential solution needs to have and compare these guidelines with existing designs.

1.1 Biking with backpacks and discomfort

In the city of Toronto only about half of bicycle usage is intended for health and sport reasons [10]. This means that around 3.5 million people cycle each year [1] using the *Bike Share* program. Studies reveal that biking even without a backpack leads to lower back pain [4].

Many students use backpacks everyday for school. Studies show that backpack usage produces back pain proportional to the backpacks weight [12]. Therefore, we saw an opportunity for an engineering design that could transfer the weight of the backpack from the user to the bicycle, thus reducing the stress on the lower back. This design brief serves the purpose of providing guidelines and objectives for a specific design to solve the opportunity presented.

1.2 Design space

The design should allow the user to leave their backpack attached to the bike thus removing all weight from the user's spine. The design should be focused towards Tangerine's *Bike Share* classic bikes present in the city of Toronto. The design space focuses on commuters who use backpacks as a mean of carrying things while riding a bicycle. Bags that do not fit in the front basket are to be considered. The design should be focused towards users whose routes consist of up to 10km. The design should also consider the average backpack weight and size (Appendix A) [7] [2].

1.3 Stakeholders

The stakeholders are the parties interested in the design and those who the design will affect. The NGOs (Needs, Goals and Objectives) were written with them in mind to ensure the final design meets their expectations and does not impact them negatively. Designers should continue to consider their points of view throughout the design process.

1.3.1 Bike Share Users with Backpacks: Primary

For the users of this solution, it must be convenient to use the product without hindering their biking ability. This includes affecting the balance, weight, or field of view their bike naturally affords, as per Goal 2 (Section 2.2). The solution should also be ergonomic and easy to immediately understand, allowing for seamless adoptions and reducing any potential learning curve, as seen in Goal 3 (Section 2.3).

1.3.2 Praxis Students: Primary

As the designers of the solution, Praxis Students want to ensure that the solution is effective and usable for the end user. This includes the geometry, weight, compatibility, and functionality of the solution all being optimal, as per all goals stated.

1.3.3 Toronto Drivers: Secondary

Bikers often share to the road with drivers so considerations must be made to not significantly impact other people's driving experience. Thus, the solution cannot impact the visibility, width, or speed of bikes in a way which will inherently affect drivers, who must share the road with bikers, as per Goal 1 (Section 2.1).

1.3.4 Other Bike Share Users: Secondary

All other users of the Toronto *Bike Share* system who want to maintain current or improved service quality. They may have to deal with the influences of the solution, including the impact the solution has on the biking ability of those who use it, as seen in goal 2 (Section 2.2).

1.3.5 City of Toronto Bike Share System: Tertiary

The city of Toronto wants to maintain their current *Bike Share* system and enforce their user agreement that you must bike safely and with caution to avoid causing any damage to the bikes. Thus, they act as a regulatory body enforcing that the solution does not affect the usability of the bikes, as per Goal 2 (Section 2.2).

1.3.6 Government of Ontario: Tertiary

The Government of Ontario has laws for the types of vehicles allowed on specific pathways and even though rules on biking attachments are quite lenient, any attachment must not impede the rider's ability to follow preexisting laws (e.g. make a left turn and maintain clear visibility of surroundings), as per Goals 1 and 2 (Section 2.1) (Section 2.2) .

2 NGOs

The need is a portable system which allows the user to ride a bicycle with a backpack without taking load to their spine. It must be compatible with Tangerine bikes without interfering with the visibility of the user nor the stability of the bike. Additionally, it must support heavy loads while having attachments which are easy to use.

2.1 Goal 1: Limit geometry to be compatible with Tangerine bike and environment

It is necessary that the design's geometry does not damage the bike, interfere with the end user's field of view, nor extend outside of the bike line while mounted.

2.1.1 Objective 1.1

The design shall be mountable on the Tangerine bike such that it has no contact with the bike other than its supports. This shall prevent the design from scratching the Tangerine bikes, which have a unique geometry as outlined in Figures 3 and 4. While mounted, the design in its expanded state shall not overlap with any section of this side view of the bike.

2.1.2 Objective 1.2

Whilst cycling in the city, the user will be bound by the bike lanes he rides in to prevent interference with surrounding traffic. Therefore, the width of the design in its expanded state should be at most 1.0m in order to maintain a smaller footprint than the minimum cycling lane width of 1.2m (Figure 10).

2.1.3 Objective 1.3

The design should not block the users view. It is important that the rider maintains a clear view of the road so that they can interact with surrounding cycling traffic normally. Therefore, the height of the top of the design in its expanded state should be at most 1.0m in order to remain below the average eyeline of 1.5m defined in Book 18 of the Ontario Traffic Manual [11].

2.2 Goal 2: Maintain bike stability and usability

The design must not interfere with the stability or handling of the bicycle. While in use, the bike should remain safe and easy to control. Since stability depends on weight distribution, the design should be adjusted accordingly.

2.2.1 Objective 2.1

The attachment should position the backpack's mass close to the bike's center of gravity to avoid additional moments that can destabilize the ride. According to ISO 11243:2023, the center of gravity should remain within 40 mm of the longitudinal centreline [5].

2.2.2 Objective 2.2

The design must not interfere with normal cycling motions. The rider should be able to complete a full pedaling cycle and fully rotate the handlebars in both directions without interference.

2.2.3 Objective 2.3

A maximum load capacity should be established in order to ensure that the design is not built to be stronger than the bike itself can support. The design shall have a maximum load capacity that adheres to ISO 11243:2023 Section 4 (Figure 9) depending on the attachment type.

2.3 Goal 3: Easily attachable and portable

Since these are to be used in parallel with the Tangerine city bikes, the user will not be able to leave it on the bike after they dock it. A key differentiating factor of this design must be how easy it is to take on and off and how portable it is. The attachments must also be easy to use and learn.

2.3.1 Objective 3.1

The solution's attachment points to the bike and backpack will provide various forms of feedback including visual, auditory, and haptic to make it more accessible and to allow effortless learning (Figure 8). The attatchement mechanisms implemented must be in accordance to ISO 9241-112:2017 [9].

2.3.2 Objective 3.2

The average time taken for an average user to connect or disconnect their backpack from a Toronto *Bike Share* bike should not exceed one minute, as this is beyond the average attention span of person and thus would be very inconvenient to anyone using the solution [3].

2.3.3 Objective 3.3

The mechanism used to attatch the solution to the bike is ergonomic and doesn't cause localized fatigue in the user's hands, in accordance to ISO/TS 9241-430:2021. Along with optimal join angles and minimal arm and elbow movements, this will make it seamless for the user to attatch and detatch the solution from their bike (Figure 7).

2.4 Goal 4: Can Hold Average Backpack

The design must be able to reliably support the average backpack.

2.4.1 Objective 4.1

The design shall have a minimum load capacity of at least 10kg. The value of 10kg is just over the average backpack mass for older adolescents (such as first year university students) of 9kg (Figure 2). Surpassing this average allows for most users to be supported.

2.4.2 Objective 4.2

The design shall be able to carry a load with a base of at least 20cmx35cm, and have some method of keeping the load from falling. These dimentions are the upper end of the average as shown in Figure 1. This objective will be met once a backpack of the given dimensions can be attached to a Tangerine Bike with the design and taken around a city block with a speed of at least 20 km/h without falling.

3 Reference designs

Existing attachments for bicycles function but often fail to meet certain DfX usability criteria. Many are designed as permanent fixtures, making installation and removal time-consuming while also limiting portability. The red arrows in Figures 5 and 6 show examples of permanent attachments.

Additionally, some existing solutions are incompatible with Toronto's Tangerine *Bike Share* models, as they do not permit seat removal, a step which is required for installation. Furthermore, although some current solutions are collapsable, as seen by the green arrow in Figure 5, no solutions offer attachments to backpacks for portability. This highlights a specific need for developing designs that are compatible with shared bicycles while also supporting attachment to existing personal items such as backpacks for a fully integrated user experience.

4 Conclusion

Ultimately, through the provided constraints, one can design an effective solution that can prevent one from carrying their backpack on them when using the Toronto *Bike Share* system. While this significantly improves posture and spinal comfort, it's imperative the design does not impede on the safety or convenience of the user. Thus, the provided goals state that the design must follow geometry, weight, stability, and usability constraints to create an effective design. While many designs exist for carrying luggage on bikes, they're inconvenient to constantly detach, reattach and transport; thus creating the need for a solution tailored to people who rely on the Toronto *Bike Share* to travel to school everyday.

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6 Appendices

6.1 Appendix A

2. Typical External Dimensions

Standard everyday backpacks focus on a balance between capacity and ergonomic comfort. The most common dimension range is:

Dimension	Metric	Imperial	Notes
Height	45–50 cm	18–20 in	Includes top handle; aligns with torso length
Width	30–35 cm	12–14 in	Accommodates laptops up to 15"
Depth	15–20 cm	6–8 in	Slim enough for narrow aisles or subways

These external measurements translate to a total external volume of 8 000–14 000 cu in (130–230 L), but internal usable volume (after subtracting material thickness and seam allowances) is 20–30 L for standard packs.

3. Internal Vs. External Capacity

- **Internal Usable Space:** Includes main compartment, top/lid pocket, and any zippered mesh pockets.
- **Excluded Storage:** Side mesh pouches, hip-belt pockets, and external lash points typically are omitted from "official" volume ratings, so your "25 L" pack might actually offer 27–28 L when including these extras.

4. Why The 20–30 L Range?

- **Daily Essentials:** A 20 L pack comfortably fits a 13" laptop, charger, documents, water bottle, and lunch box.
- **Versatility:** 30 L covers weekend carry-on needs or heavier gear without excessive bulk.
- **Ergonomics:** Packs larger than 30 L often require more robust frames and hip belts, shifting them into specialty or travel-pack categories.

Figure 1: Average backpack dimensions [7]

Age	Gender	Mean weight (kg)	Percentage of body weight (%)
11	F	9	18.75
12	M	5.72	12
	F	6.14	12.58
13	M	6.68	13.68
	F	6.06	12.88
14	M	6.23	13.1
	F	6.25	13.1
15	M	7.34	14.29
	F	7.32	15.07
16	M	6.57	12.6
	F	6	12
17	M	6	12
	F	9	17

Figure 2: Mean weight of backpack as compared to body weight [2]

6.2 Appendix B

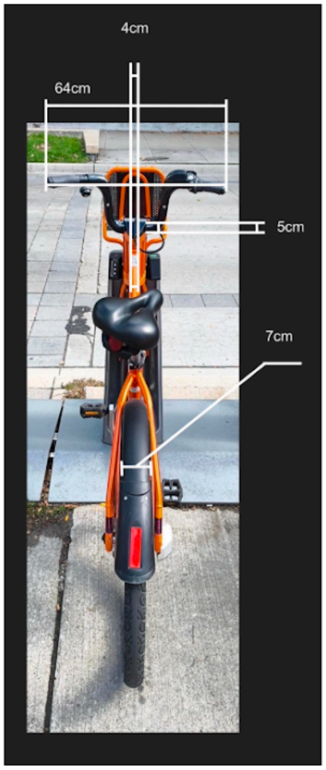


Figure 3: Ride share Toronto bike dimensions

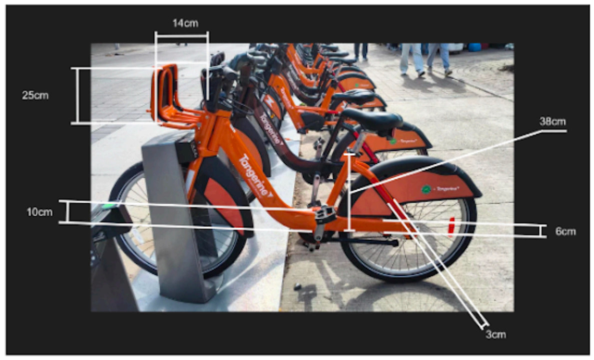


Figure 4: Ride share Toronto bike dimensions

Figure 5: Collapsable reference design [6]

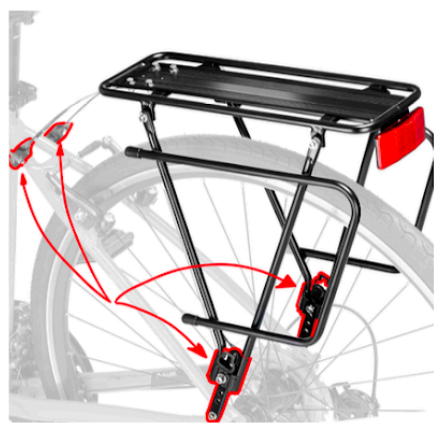


Figure 6: Not collapsable reference design [13]

6.3 Source Extracts

4.2 Modalities and media

Modalities are based on human senses:

- — visual (seeing);
- — auditory (hearing);
- — tactile or haptic (touching);
- — olfactory (smelling);
- — gustatory (tasting).

While humans can perceive information based on all modalities, the visual, auditory, and tactile or haptic modalities are the ones commonly used in ICT systems. While the principles apply across all modalities, these three modalities provide the basis for the specific recommendations in this document.

Media are different means of presenting information within one or more modalities [e.g. text (written, spoken, signed, or tactilely presented), images (visual, tactile), sounds, movies, etc.]. Text is the most flexible form of information because it can easily be rendered in each of the visual and auditory modalities. While non-textual information can be more efficient and satisfying in some circumstances, it has the disadvantage of not easily being transformed between modalities. While this document contains some media-specific guidance, it does not deal with all possible guidance on the use of any one medium.

It is necessary to perceive (sense) information before it can be understood (i.e., the meaning can be identified). If users miss perceiving information (due to inattention or due to not being able to utilize the modality in which it is presented), then they will not have it available for understanding. However, users can also perceive the existence of some information that they cannot understand (without further information to help them in this understanding).

4.3 Accessibility

Interactive systems presenting information shall ensure that the presentation of information conforms to ISO 9241-171.

NOTE 1 ISO 9241-171 provides requirements and recommendations on software accessibility.

NOTE 2 The presentation of the same information in more than one modality or medium increases accessibility.

4.4 Action guidance

Information should be presented in a way that it supports the user's intended actions rather than explaining what the system wants the user to do. The design of a system must guide the user in performing the intended actions, minimizing the need for additional instructive information. However, additional explicit instructive information can be applied wherever identified as necessary.

NOTE Regarding the presentation characteristics of user-interface elements, action guidance is also referred to as "affordance" or "cueing the user".

4.5 Information presentation and aesthetics

While aesthetic effects contribute to the user experience, effects that can reduce overall usability must be avoided.

NOTE The use of specific effects for aesthetic purposes (such as flashing images, music, or vibration patterns) can cause a variety of problems for users (including distractions and difficulties in perception).

5 Introduction to the principles for presentation of information

5.1 Overview

The principles in this document address common usability issues that arise in the presentation of information, when designing user interfaces. They address the ways in which information presented in the design of user interfaces supports effectiveness and efficiency and can lead to increased user satisfaction. These principles are:

- — detectability;
- — discriminability;
- — conciseness;
- — unambiguous interpretability;
- — freedom from distraction;
- — consistency (internal and external).

The individual principles are described and each of the principles is accompanied by a non-exhaustive list of illustrative recommendations at various levels of detail. Designs in accordance with these recommendations will help prevent users experiencing typical usability problems.

Figure 7: Types of feedback to enable accessibility [9]

3.1

localized fatigue

reduced ability of muscles to generate force that occurs with prolonged repeated or sustained activities of the hands and arms

Note 1 to entry: This can be measured as reduced strength or perceived as weakness, discomfort, pain, tremors or altered motor control of the hand or arm. The symptoms can occur at the time the activity is performed or hours later.

Note 2 to entry: The fatigue considered here is also known as peripheral fatigue. Central fatigue (e.g. central nervous system) is not considered.

3.2

anatomical structures and landmarks of the hand

commonly agreed terminology for structures, regions or surfaces of the hands, which facilitate description of the location of the hand in space

Note 1 to entry: Use medical anatomical terms to describe anatomical structures and landmarks, for example palmar, dorsal, radial, ulnar surfaces; digits (1 to 4 = index, middle, right, small); thumb; finger and thumb joints [carpometacarpal joint (CMC), interphalangeal joint (IP), proximal interphalangeal joint (PIP) and distal interphalangeal joint (DIP)].

3.3

joint posture

position of the joints of the upper extremities

Note 1 to entry: Some joint postures of interest are fingers and thumb in flexion/extension and abduction/adduction; wrist in extension/flexion and ulnar/radial deviation; forearm in pronation/supination; elbow in flexion/extension; and shoulder in flexion/extension, abduction/adduction, internal/external rotation and elevation.

Note 2 to entry: The terms used to describe joint postures can be applied to both static joint postures and joint movements. A static posture is described in degrees relative to a reference frame (see ISO 9241-400 and Reference [11]). Joint movement directions are described using the same terms.

3.4

optimal joint posture

joint posture where muscles are in the least activated state

Note 1 to entry: Typically, optimal joint postures are postures where the muscles that control joint movement are in their least activated state. This may also be referred to as neutral posture, i.e. a position that parts of the body assume when relaxed. Optimal joint postures are influenced by the posture of adjacent joints, the mass of adjacent body segments, the direction of gravity relative to the joint postures and other factors.

EXAMPLE:
Wrist (for power grip): 20° of extension, 0° to 15° of ulnar deviation and a grip diameter of 3 cm to 5 cm; forearm: 0° to 60° of pronation; elbow: 0° to 90° of flexion; shoulder: 0° to 20° of flexion, 0° to 20° of abduction and 0° to 60° of internal rotation.

3.5

hand microgesture

movement or posture of the fingers and hand that does not involve movement of the shoulder or movement of the elbow in flexion or extension

Note 1 to entry: Hand microgestures may also be called finger gestures. Hand microgestures can include forearm pronation and supination.

Figure 8: Ergonomics of attachment mechanism [8]

4 The restrictions of maximum load capacity for the types of non cycle specific luggage carrier

Manufacturers of non cycle specific luggage carrier shall take into consideration any restrictions laid down in Table 1.

For cycle specific luggage carrier, the manufacturer is responsible for determining the maximum load capacity.

For designs exceeding the capacity restrictions, a risk assessment should be performed by the manufacturer in particular addressing the effect of the higher load capacity and to identify suitable measures to address the identified risks.

In Table 1, the maximum limit (if any) for the load capacity is indicated for each type of non cycle specific luggage carrier that falls within the scope of this document. The applicable requirements and test methods differ according to the type and maximum load capacity.

Table 1 — The restrictions of maximum load capacity for the types of non cycle specific luggage carrier

Type of luggage carrier	Rear			Front		
	Normal rear luggage carrier	Beam carriers		Above wheel front luggage carrier	Low-load front luggage carrier	Front mounted container
		Seat post-mounted beam luggage carrier	Frame-mounted beam luggage carrier			
Restriction of maximum load capacity, kg	no limit	10	27	10	18	10
NOTE Maximum load capacity does not include the battery mass if so equipped.						

NOTE Examples of luggage carrier configurations are shown in Annex C.

 3

Figure 9: Maximum load limits in accordance to luggage attachment types [5]

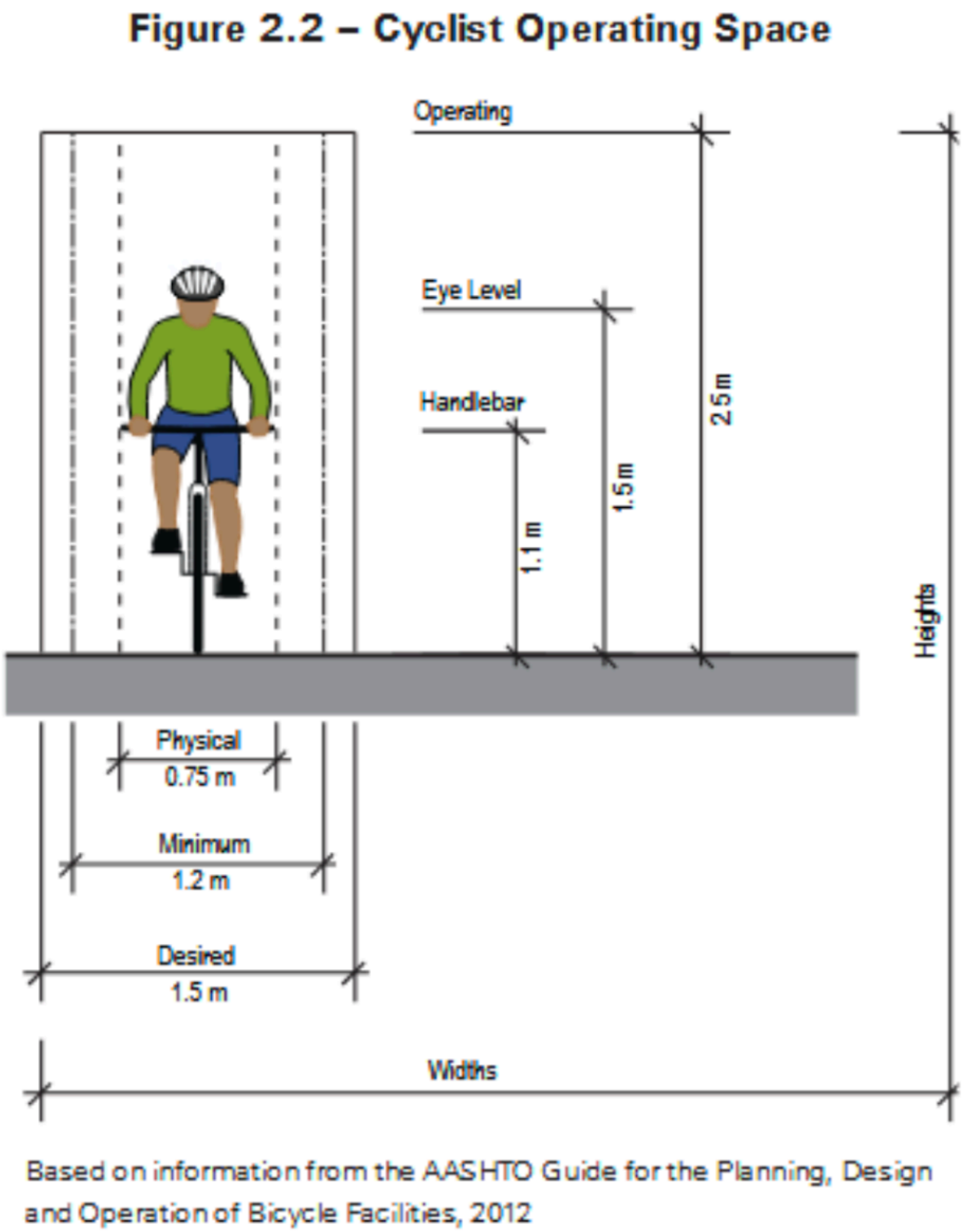
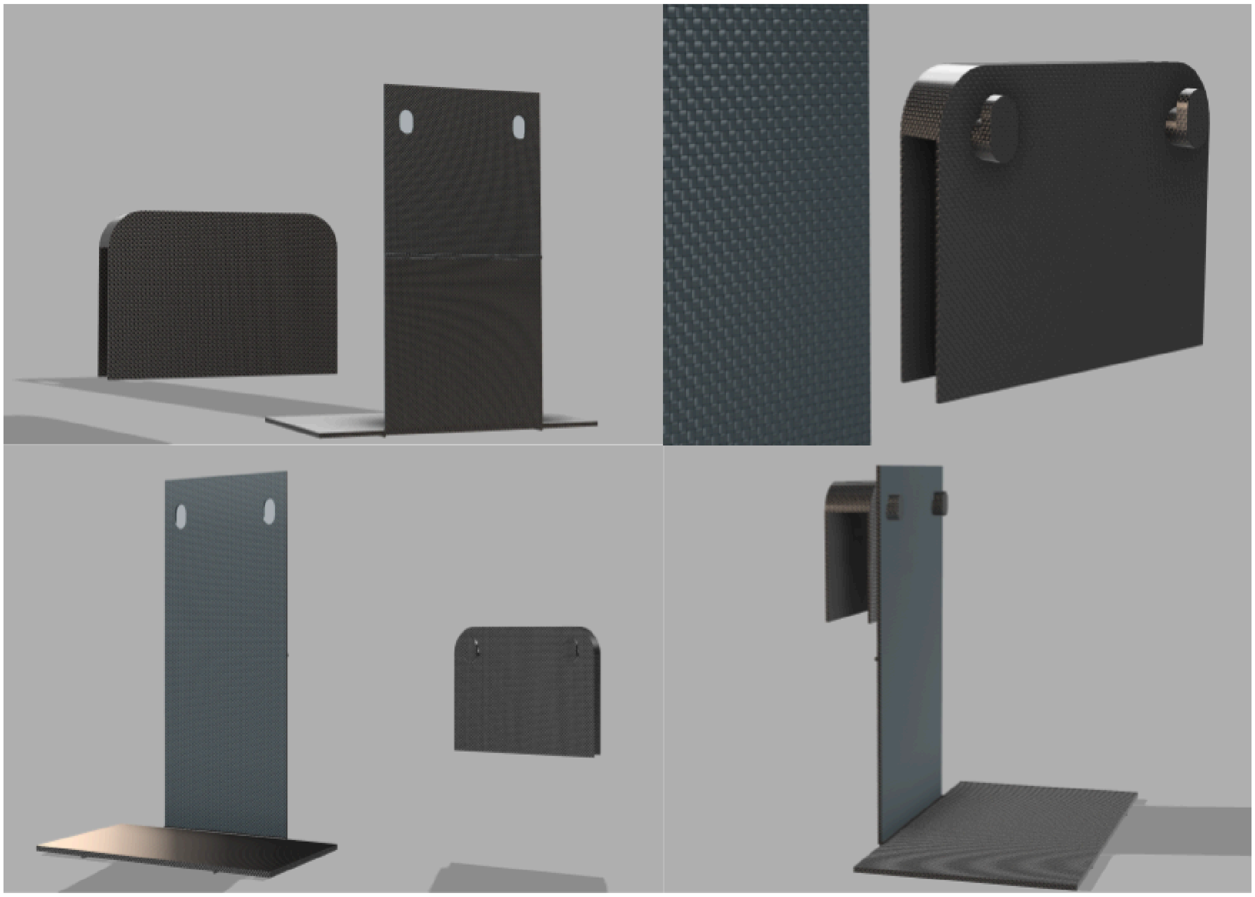
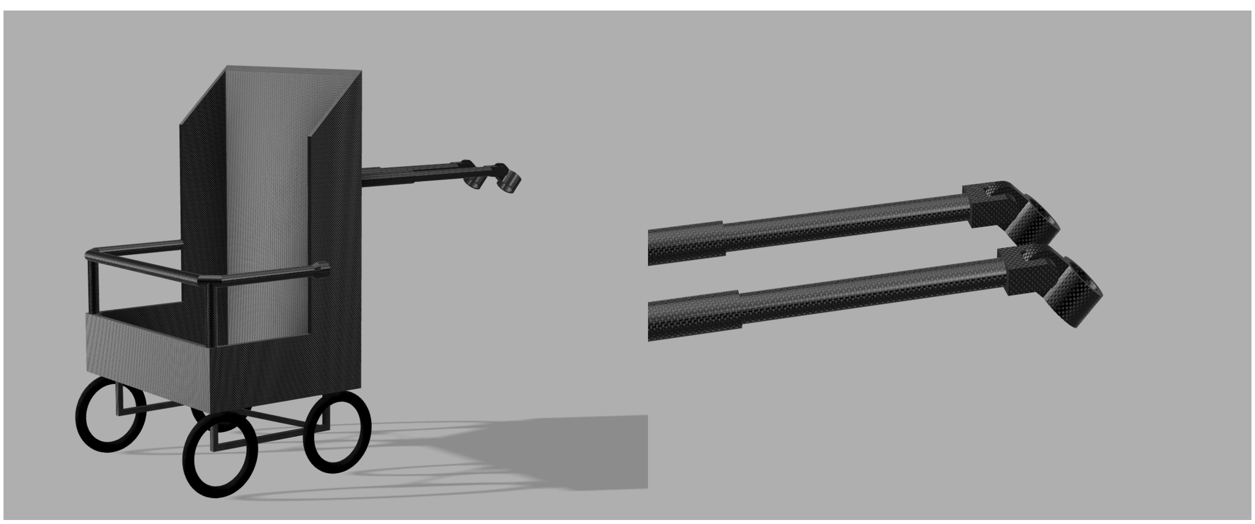


Figure 10: Dimensions of Toronto bike lanes [11]

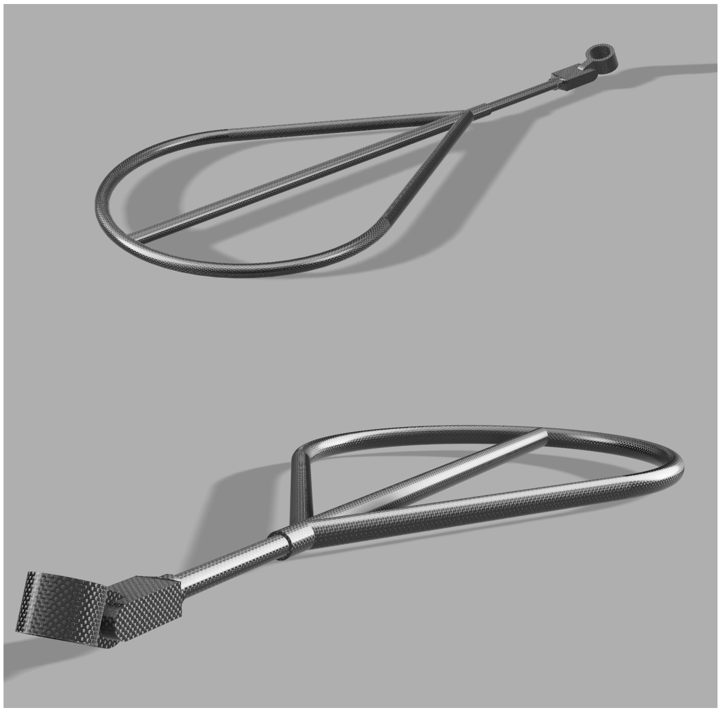
Appendix B: Various Angles of All the CAD Models



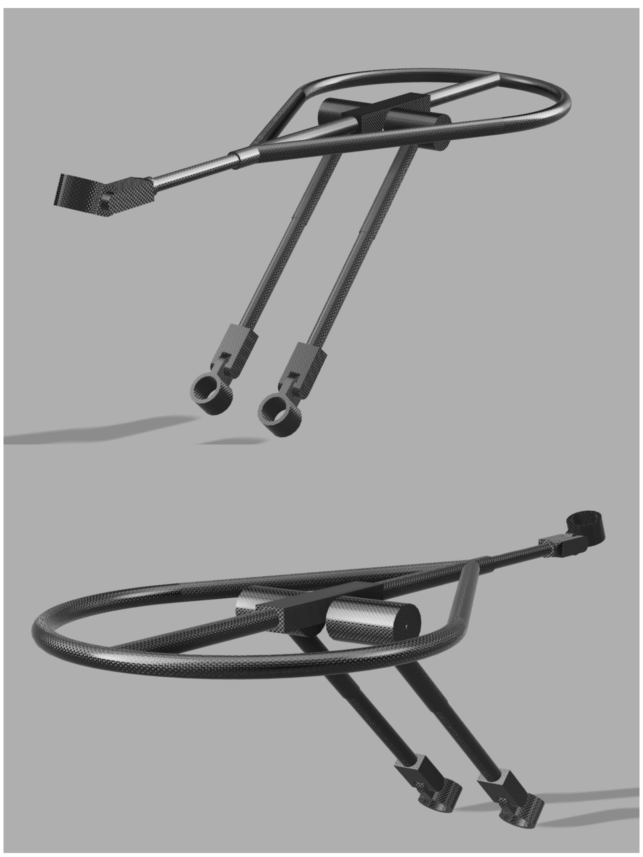
Design 1 CAD model



Design 3 CAD model



Design 4 CAD model



Design 5 CAD model

Appendix C: Explaining Angular Momentum, Angular Velocity, and Moment of Inertia

Angular Momentum: Measures the tendency to which an object wants to keep rotating, where a higher angular momentum will induce a force onto your bike for it to be less balanced. Angular momentum is proportional to the angular velocity times the moment of inertia.

Angular Velocity: Measures the rate at which an object changes its orientation around an axis.

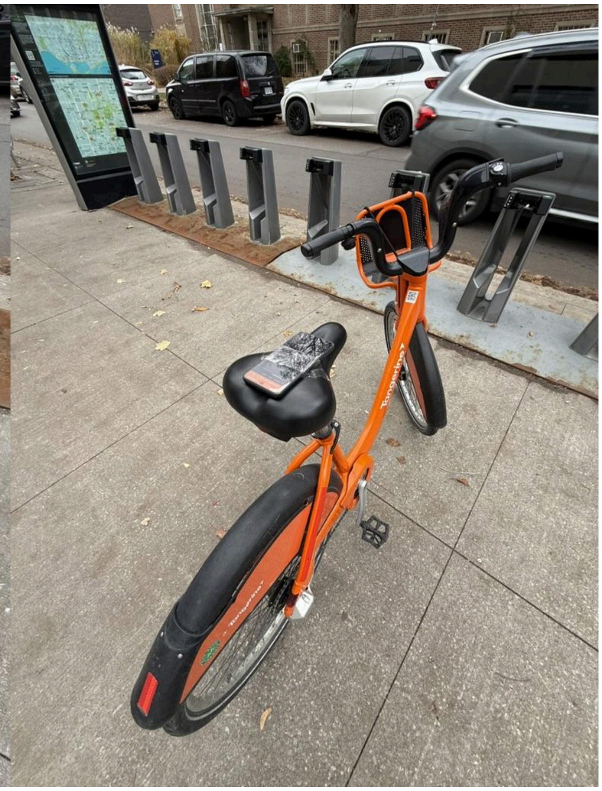
Moment of Inertia: Measures how much a body resists a change in its current rotation. The moment of inertia increases as the design moves higher off the ground from the bike and the self weight of the design increases. Within the context of this report, the moment of inertia makes it harder for the bike to continuously stay balanced because the bike will resist the rider trying to constantly balance it much more. Thus, a design which is higher off the ground will severely decrease the rideability of the bike.

Appendix D: Testing Images

Testing for cantilever position

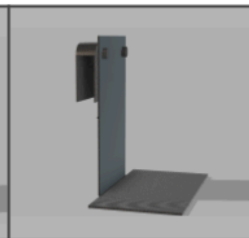
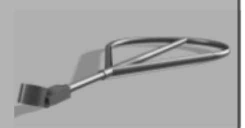

Testing for front basket position

Testing for trailer position

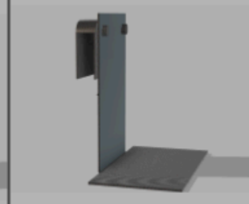


Testing for back axle position

Appendix E: Additional Pugh Charts

Designs / Metrics	Reference 			
Size (Storage) (W x H x L in cm)	=	+	+	+
Mass (kg)	=	+	+	+
Acceleration (m / s^2)	=	+	-	-
Angular Speed (rad / s)	=	+	-	-
Number of Steps in Set-Up (#)	=	=	-	+
Number of Parts (#)	=	+	+	+

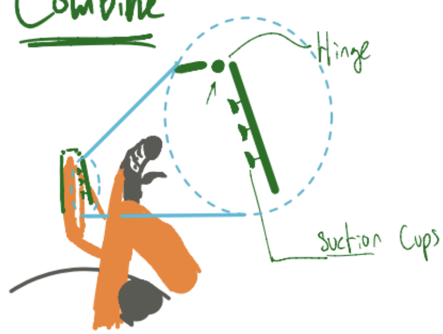
Designs Metrics			Reference 	
Size (Storage) (W x H x L in cm)	-	+	=	~ =
Mass (kg)	-	-	=	+
Acceleration (m / s^2)	+	+	=	-
Angular Speed (rad / s)	+	+	=	-
Number of Steps in Set-Up (#)	+	+	=	+
Number of Parts (#)	-	+	=	+

Designs / Metrics				Reference 
Size (Storage) (W x H x L in cm)	-	+	~=	=
Mass (kg)	-	-	-	=
Acceleration (m / s^2)	+	+	+	=
Angular Speed (rad / s)	+	+	+	=
Number of Steps in Set-Up (#)	-	-	-	=
Number of Parts (#)	-	-	-	=

Appendix F: SCAMPER

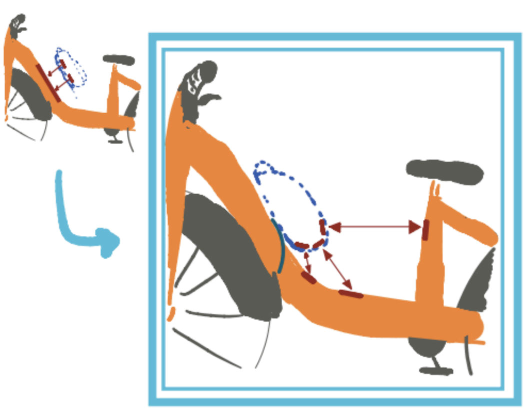
SCAMPER

Combine



- Combine natural fit w/ suction cups
- Hinges b/w natural fit parts
    - Suction cups allow for more bending/hinges, and in turn a smaller folded footprint effective volume

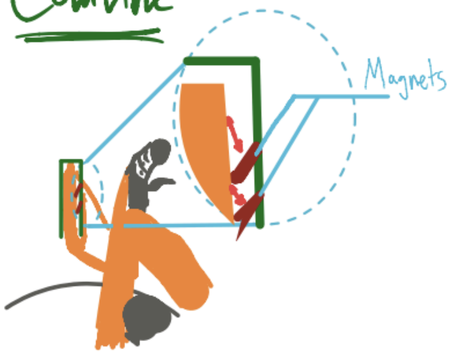
Modify



- Research showed that the aluminum body of the Tangerine bikes has a stronger repelling force than attraction force
- To take advantage of this, we modified the magnet's use to be repelling the body, being used for suspension, and leaving centralization to be done by a frame

SCAMPER

Combine



- Combined the use of magnets into natural fit
- Rather than using magnets for attachment itself, we can repurpose/adapt them to strengthen the hold that a natural fit can have
- The upward tilt of the magnets means they will push down on the natural fit frame, holding it more steady in place

Minify + Put to other use

- The idea of a natural fit can be doubled and scaled down within its own design to make it more modular.
- By having the section that attaches to the bike have pertrusions with a natural fit in the bag holder section allows both parts to separate for easier storage.