WheelWatch : MVP Report

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1. Executive Summary

Our product, the WheelWatch, is created through the collaborative efforts of a team comprising Declan Bohley, David Park, Marc Reta, and Taimur Shaikh in developing a working prototype. Leveraging their individual expertise in hardware, backend development, and frontend design, the team successfully navigated challenges such as scheduling conflicts and hardware integration issues. Through effective task delegation, transparent communication, and the adoption of project management tools like GitHub, the team achieved significant milestones in the creation of their prototype.

Successes in the project included the establishment of a conducive working environment where feedback was encouraged, leading to enhanced collaboration and a shared commitment to project success. The team's ability to identify and address bottlenecks promptly, coupled with a proactive approach to learning and self-improvement through techniques like pair programming and code reviews, contributed to the overall quality and success of the prototype. The product features a range of innovative functionalities, including SIM card notifications, GPS tracking, tampering alerts, and accelerometer detection, catering to the security needs of diverse user segments such as universities and bike rental companies. By prioritizing user-friendly design elements and robust security measures, the team aims to position their product as a leading solution in the smart lock market, offering consumers a reliable and technologically advanced security option for their bikes.

The team is aiming to revolutionize bicycle security and enhance the cycling experience for riders worldwide.

2. Company Synopsis

Introducing the team that created the first prototype of the WheelWatch:

Declan Bohley: A 3rd year Electrical Engineering student at the University of California, San Diego

David Park: A 4th year Electrical Engineering student at the University of California, San Diego, with a background in Python, C++, Javascript, System Verilog, and CAD.

Marc Reta: A 4th year Computer Engineering student at the University of California, San Diego with a background in Java, Javascript, Python, Systemverilog, and C++ through classes such as CSE 110, CSE 112, ECE 111, and ECE 140A.

Taimur Shaikh: A 4th-year Cognitive Science student at the University of California, San Diego specializing in Human-Computer Interaction. He has experience in DevOps and Cybersecurity, with skills in Terraform, CI/CD pipelines, and AWS.

We are well positioned to build this product since each of us has necessary skills to complete a working prototype. David has the most experience with hardware and CAD which makes him the perfect candidate to create the 3D print of the shell that will store our ESP32, buzzer, accelerometer, and U-Lock. Marc and Declan have the most experience with backend which makes them the perfect candidate for creating the Arduino code that will communicate the ESP32 with the buzzer, accelerometer, and website application. Taimur is the most experienced with frontend which makes him the perfect candidate for creating the design of the website application through CSS and HTML.

Our mission as a company is to revolutionize bicycle security by providing a smart, reliable, and user-friendly theft-discouraging bike lock, enhancing the cycling experience for riders worldwide. Our vision as a company is to become the leading provider of innovative bike security solutions, empowering cyclists with peace of mind and promoting sustainable transportation.

3. Market Overview

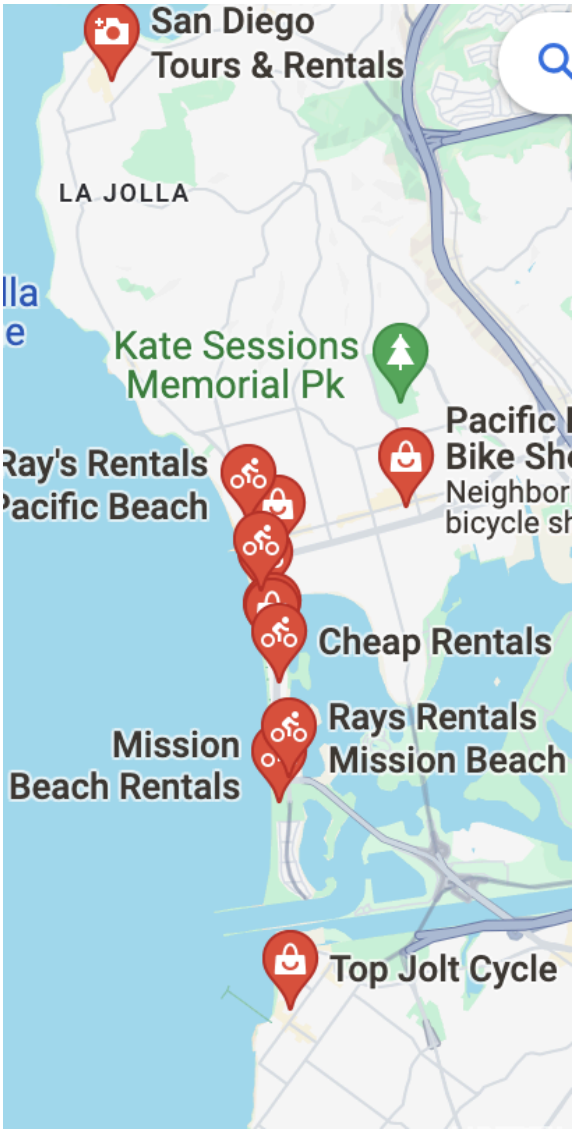
Business to Customer (B2C)

When analyzing the market for our product we find two main addressable areas. The most important one is our business to customer sales for bicyclists who live in bikeable areas that are densely populated and have alot of foot traffic. In California, especially southern California, our product will be popular among college students. Any bikeable/walkable city would show popularity for this product but college students are a main focus for us. Especially since we are focusing on making this product affordable compared to other very expensive smart locks that are available. So the affordability of our product is important to how we are analyzing where our product would be popular in the market. Take UCSD for example where there are about 35,000 undergraduate students and over 18 million students attend college in the US every year. Also around 50% of college students have ridden a bike according to students (Harris, 2011; Moudon et al., 2005). While not all of these students are consistently using bikes to transport themselves on campus many of them are. And bike security is a must for high population areas like college campuses where theft is common. This would also be a great product for bikeable high population cities like NYC where many people bike everyday to avoid traffic showing that this could be a useful product across the country. Overall the focus is on people who need affordable

options for bike security as losing a bike could be quite a financial hit and many times bike locks that provide extra security beyond basic measure are too expensive.

Business to Business (B2B)

A different aspect of the market that we have analyzed that is showing itself to be a good direction to pursue is marketing to bike rental/bike tourism companies.Looking at a place like San Diego there is a lot of rental companies for biking since San Diego is a very popular tourist spot and great for a sunny vacation.



A quick picture of some of the bike rental places you have on the coast in San Diego shows how lucrative bike renting is as a business. Now having an added level of security for these bike rentals gives the company a great way to cut down on the cost of these being stolen and having these locks being able to communicate to the user updates about their status are great features that can be added to the experience of renting a bike for short use. Even if the renters are liable for the loss of the property it is a win-win situation for all parties if the bikes have greater security than just normal U-locks. Also due to their affordability they can be purchased at scale with these rental businesses. The high end bike locks with smart features that

reach 200-300 dollars in cost aren't a viable option when working with a lot of bikes for a lot of users.

4. Competitive Analysis

Competitors

1. LINKA

- **Price**: $150+
- **Strengths**:
    - Marketed as “unbreakable”
    - Highly durable
    - Tampering detection via Bluetooth
- **Weaknesses**:
    - Very heavy and expensive
    - Bluetooth has limited range (~30 feet) and poor penetration through obstructions (e.g., walls)
    - High cost may result in significant loss if the lock is eventually picked or broken

2. I LOCK IT

- **Price**: $140+
- **Features**:
    - Tampering detection via Bluetooth
    - Lock and unlock via app and nearness detection
    - GPS tracking
- **Weaknesses**:
    - Bluetooth has limited range (~30 feet) and poor penetration through obstructions
    - Security concerns with nearness detection in public spaces
    - High price point

Our Product - WheelWatch

- **Price**: $40-50 + $7 monthly subscription
- **Features**:
    - Uses SIM cards for notifications, providing extensive range without issues
    - GPS tracking included
    - Audible tampering alerts (beep for first detection, siren/alarm for subsequent detections)
    - Comparable strength to other locks, though not marketed as unbreakable
    - Requires a monthly subscription (~$7) for SIM card activation and usage
    - Various lock types and accessories, including app-controlled locks
    - Tampering detection via accelerometer and hidden wire in the shackle
    - Solar panel for potentially near-unlimited battery life

Competitive Analysis Breakdown

1. **Feature Comparison**

    - **Range and Connectivity**:
        - Our product's SIM card-based notifications provide superior range and reliability compared to competitors' Bluetooth-based systems.

    - **GPS Tracking**:
        - Both our product and I LOCK IT offer GPS tracking, but our product's implementation through SIM cards offers more robust connectivity.

    - **Tampering Detection**:
        - Our product's tampering detection system is more versatile with both accelerometer and hidden wire detection, combined with auditory alarms.

    - **Power Supply**:
        - The inclusion of a solar panel in our product offers a significant advantage in battery life over competitors.

2. **Price and Value Proposition**
    - Our product is positioned at a significantly lower price point ($40-50) compared to Linka Lock ($150+) and potentially I LOCK IT.
    - The monthly subscription fee for SIM card activation (~$7) is an additional cost, but the benefits of reliable connectivity and GPS tracking justify this expense.
    - The combination of affordability, robust features, and long-lasting power supply creates a compelling value proposition.

3. **Market Position and Potential Whitespace**
    - **Affordability**: There is a clear market gap for a high-feature, affordable lock. Competitors focus on high-end pricing and premium features, while our product offers similar key features at a lower price point.
    - **Reliability and Range**: The use of SIM cards and solar power addresses common pain points (range issues, battery life) that are not fully resolved by competitors.
    - **Flexibility**: Offering a variety of lock types and accessories, along with app-controlled options, appeals to a broader customer base with diverse needs.
    - **Subscription Model**: Although a subscription fee is required, the ongoing revenue model supports continuous improvement and customer engagement.

<u>Whitespace Opportunity</u>

1. **Cost-Effective Smart Locks**: Target budget-conscious consumers who need reliable security without the high upfront cost.
2. **Enhanced Connectivity**: Leverage the superior range and reliability of SIM cards to market to users frustrated with Bluetooth limitations.
3. **Sustainable Power Solutions**: Promote the solar panel feature to environmentally conscious consumers and those concerned with battery life.
4. **Customizable and Expandable Options**: Develop a product line that offers various lock types and accessories, appealing to users looking for tailored solutions.

By positioning our product within this whitespace, we can attract a significant segment of the market that is currently underserved by high-cost, limited-range smart locks. This approach ensures differentiation from existing competitors and capitalizes on identified market gaps.

5. Customer Personas, full interview details, and Acquisition Plan

Customer Personas

Khai is a student who commutes to UCSD by bike. He is likely balancing academics, possibly part-time work, and social activities. Khai prefers a heavier, more durable bike lock for added security. His primary concern is the physical robustness of the lock, indicating that he values durability over smart features. Although Khai is not very interested in smart lock features, he does appreciate tampering notifications. He is willing to pay up to $60 for a reliable lock, placing him at the higher end of the student budget spectrum. However, he may require some education on the benefits of smart features beyond tampering notifications to fully appreciate their value.

Yash, another student commuting to UCSD by bike, is managing a tight budget typical of many students. He is interested in technology and smart features, specifically wanting tampering notifications and the convenience of app control. Initially, Yash budgeted $30 for a bike lock, but he is open to spending more ($40-50) for added value. Despite recognizing the product's worth, he is hesitant about the $7/month subscription fee due to budget constraints. Flexible payment options or student discounts could help alleviate his cost concerns and make the product more appealing to him.

Josh is a student who rides his bike recreationally rather than for commuting, indicating that he likely values leisure and fitness activities. He prefers a chain lock with tampering alarms and finds the product interesting, especially if it is compatible with a chain lock. Josh suggests expanding the product line to offer more options, which would ensure compatibility with his

preferred lock type. Given his recreational use, he might perceive less frequent use of the lock, potentially influencing his perceived value of the product.

The UCC Bike Shop, a bicycle store near the UCSD campus, experiences peak business during move-in seasons and sees more general sales, including to non-students, during the off-season. This store offers a large selection of locks with varying features to meet the diverse needs of its customers. The shop is interested in products that can appeal to a broad range of customers, including students and general cyclists. Managing inventory to match seasonal demand is a challenge for the store, as is balancing product variety with customer preferences. Partnerships or bulk purchasing options could benefit the store by reducing costs and improving inventory management.

Additional Persona Information

Mia is an urban professional who lives in a densely populated city with heavy foot traffic. She commutes to work by bike to avoid traffic, valuing both convenience and security. Mia seeks a reliable, smart bike lock with tampering notifications and prefers app integration for easy locking and unlocking. She is willing to pay a premium for added security and convenience but needs assurance of quick customer support and reliable performance due to her busy lifestyle.

Analysis

All personas share a common concern for bike security but differ in their specific preferences for features. Price sensitivity varies among them, with students generally having lower budgets compared to potential urban professionals like Mia. While there is interest in smart features such

as tampering notifications and app control, the willingness to pay for these features varies. Khai prioritizes physical durability, whereas Yash and Mia value smart features more highly. Josh's recreational use contrasts with Khai and Yash's commuter needs. The bicycle store focuses on addressing diverse customer needs and effectively managing inventory to meet seasonal demand.

Job-to-be-Done

The primary job to be done for our smart bike lock is to enhance bike security, providing users with peace of mind through real-time notifications and effective deterrence of bike theft. By leveraging features such as SIM card notifications, tamper detection through accelerometers, and hidden wires, the lock addresses the critical need for reliable bike protection in high-traffic and densely populated areas. This is particularly important for college students, urban professionals, and bike rental companies, who all require an affordable yet robust solution to safeguard their bicycles. By ensuring that users are promptly alerted to any tampering attempts and deterring potential thieves with audible alarms, our product aims to significantly reduce the risk of bike theft and provide a sense of security for all users.

Interviews

1. **Khai (Student)**

   Interview Excerpt:

   “What specific features would you consider essential in a smart bike lock and why?”

   Khai: "I think durability is the most important. It has to be strong enough to resist physical attempts to break it. Tampering notifications would be a nice addition but not necessary for me."

Key Takeaway:

Khai values physical robustness in a bike lock above all else. While he finds tampering notifications beneficial, they are secondary to the lock's durability.

Interview Excerpt:

"How much would you be willing to pay for a smart bike lock with additional features like SIM card notifications and tamper detection?"

Khai: "I'd be willing to go up to $60, but only if it's really durable. I'm not too sold on the smart features."

Key Takeaway:

Khai's willingness to pay up to $60 is contingent on the lock's durability. He is not particularly interested in additional smart features.

2. **Yash (Student)**

Interview Excerpt:

"Would you consider purchasing a smart bike lock with these features at this price point? Why or why not?"

Yash: "I think the features are great, especially the tampering notifications and app control. The price is a bit high for my budget, but I can see the value. The $7 monthly fee is a concern though."

Key Takeaway:

Yash appreciates the smart features and recognizes the value but is concerned about the overall cost, especially the monthly subscription fee.

Interview Excerpt:

“How important is it for you to have real-time notifications about your bike's status?”

Yash: "Very important. Knowing immediately if someone is tampering with my bike gives me peace of mind."

Key Takeaway:

Real-time notifications are crucial for Yash, contributing significantly to his sense of security.

3. **Josh (Student)**

Interview Excerpt:

“What specific features would you consider essential in a smart bike lock and why?”

Josh: "For me, tampering alarms are essential. I prefer a chain lock, so compatibility with that is also important."

Key Takeaway:

Josh prioritizes tampering alarms and the lock's compatibility with chain locks.

Interview Excerpt:

“Would you prefer a bike lock that integrates with a mobile app for locking and unlocking?”

Josh: "Yes, that would be convenient, especially if it can send me alerts. I usually use my phone for everything anyway."

Key Takeaway:

Josh values the convenience of app integration, aligning well with his tech-savvy lifestyle.

4. **UCC Bike Shop (Bicycle Store)**

Interview Excerpt:

“What is your typical budget for purchasing bike locks, and what factors influence this budget?”

Shop Representative: "Our budget varies, but we look for locks that offer a good balance of security and cost. Features that prevent theft are a big selling point, especially for students."

Key Takeaway:

The shop seeks a balance between cost and security features, with a particular focus on theft prevention to appeal to their student customers.

Interview Excerpt:

“How likely are you to recommend a reliable and feature-rich bike lock to your customers?”

Shop Representative: "Very likely, especially if the lock has strong security features and is affordable. Students are always looking for good deals."

Key Takeaway:

The shop is highly likely to recommend a bike lock that combines reliability, security, and affordability, reflecting the preferences of their student customer base.

Summary of Key Takeaways

The interviews reveal that while all personas value bike security, their specific preferences and willingness to pay vary. Khai prioritizes durability over smart features, Yash values real-time notifications but is concerned about cost, and Josh prefers tampering alarms and app integration for convenience. The UCC Bike Shop seeks a balance between cost and security, with theft

prevention being a crucial selling point for students. These insights emphasize the need for a versatile product line that can cater to different customer needs and budgets.

Customer Acquisition Plan

Our customer acquisition plan focuses on targeting two main segments: college students and bike rental/tourism companies. Given the unique needs and behaviors of these segments, our approach is tailored to maximize reach and engagement.

1. College Students

Marketing Strategy:

Campus Partnerships: Collaborate with universities to promote our bike locks through campus stores, orientation programs, and student discounts. Partnering with student organizations and cycling clubs can also enhance visibility.

Social Media Campaigns: Utilize platforms popular among students, such as Instagram, TikTok, and Snapchat, to create engaging content showcasing the features and benefits of our smart bike lock. Influencer marketing can amplify our reach by leveraging college influencers to endorse our product.

On-Campus Events: Host events and demonstrations on college campuses to allow students to experience the product firsthand. Providing special offers during these events can incentivize immediate purchases.

Student Discounts and Payment Plans: Offer flexible payment options and discounts to accommodate students' limited budgets. Highlighting affordability and value can help overcome cost concerns.

Referral Programs: Implement a referral program where students can earn rewards for referring friends, fostering word-of-mouth marketing and increasing adoption among peers.

Target Schools: Focus initially on large universities with significant cycling populations, such as UCSD, UCLA, and other institutions in bike-friendly cities.

2. **Bike Rental/Tourism Companies**

Marketing Strategy:

Partnerships with Rental Companies: Establish partnerships with bike rental and tourism companies in popular tourist destinations like San Diego. Offer bulk purchase discounts and customizable lock options to meet their specific needs.

B2B Marketing Campaigns**:** Create targeted marketing materials highlighting the benefits of our smart bike lock for rental businesses, including enhanced security, real-time notifications, and cost savings from reduced theft.

Industry Events and Trade Shows**:** Attend industry events and trade shows to showcase our product to potential business clients. Networking with industry professionals can lead to valuable partnerships and bulk sales.

Case Studies and Testimonials**:** Develop case studies and gather testimonials from early business clients to build credibility and demonstrate the effectiveness of our locks in reducing theft and improving customer satisfaction.

3. **General Public in Bike-Friendly Cities**

Marketing Strategy:

Online Advertising: Use targeted online advertising on platforms like Google and Facebook to reach cyclists in densely populated, bike-friendly cities such as NYC, Portland, and San Francisco. Emphasize the affordability and advanced security features of our lock.

Content Marketing: Publish blog posts, videos, and social media content that educates cyclists about bike security and highlights the benefits of our smart bike lock. SEO optimization can help attract organic traffic from individuals searching for bike security solutions.

Local Retail Partnerships: Partner with local bike shops in these cities to stock our locks, offering in-store promotions and point-of-sale marketing materials to attract customers.

Implementation and Metrics

Tracking and Analytics: Utilize analytics tools to track the performance of our marketing campaigns and customer acquisition efforts. Key metrics include website traffic, conversion rates, customer acquisition cost (CAC), and return on investment (ROI).

Customer Feedback: Collect feedback from early adopters to refine our product and marketing strategies. Regular surveys and reviews can provide valuable insights into customer satisfaction and areas for improvement.

Scalable Expansion: Based on initial success, gradually expand our marketing efforts to additional universities, cities, and business clients, ensuring that our approach remains scalable and adaptable to different markets.

By leveraging a multi-faceted approach tailored to the specific needs and behaviors of our target segments, we aim to effectively acquire and retain customers, ensuring the success and growth of our smart bike lock in the market.

6. Product Details and Design, including UI, UX, IA, Accessibility factors

Technical design of MVP

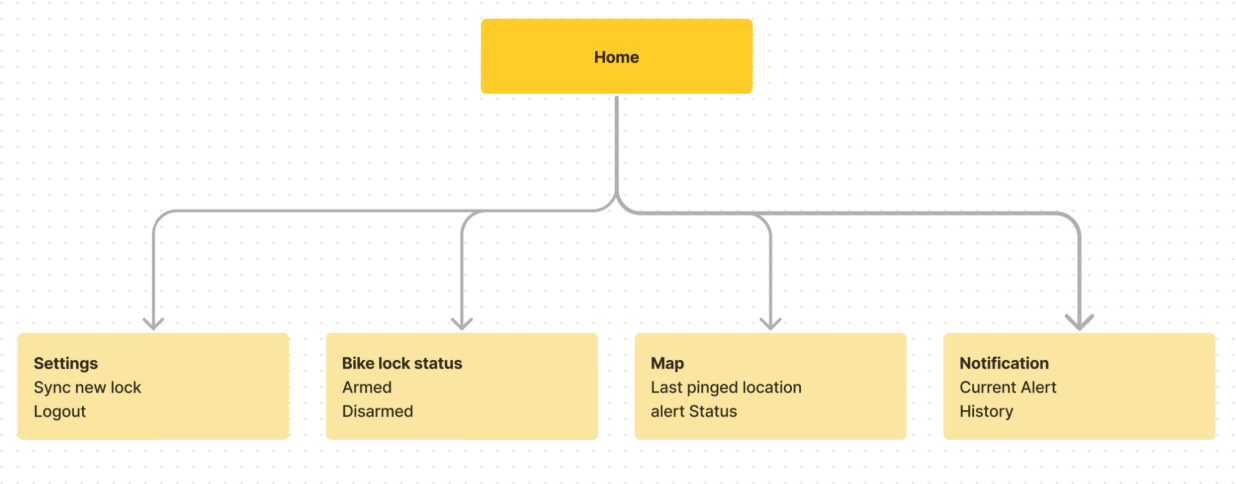


Diagram 1: App Information Architecture

The diagram above outlines the information architecture of the smart bike lock's mobile application. At the top level is the Home screen, which branches into four main sections:

Settings: This section allows users to sync a new lock or logout from their account.

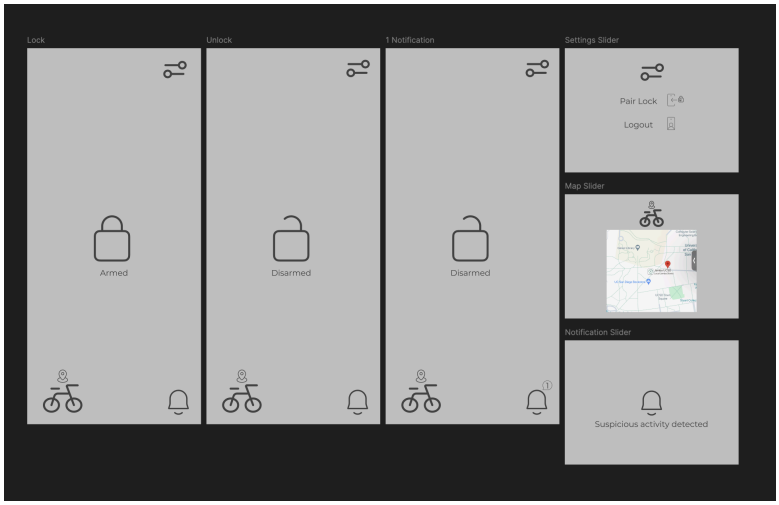
Bike Lock Status: Displays whether the bike lock is armed or disarmed.

Map: Shows the last pinged location of the bike, along with the alert status.

Notification: Provides current alerts and a history of past notifications.

Diagram 2: App UI Design Mockups

The second diagram showcases the user interface design mockups for the mobile app. It includes several screens:



Lock Screen: Shows the lock status as "Armed" with a prominent lock icon. Users can access settings from this screen.

Unlock Screen: Indicates the lock status as "Disarmed" with an open lock icon.

Notification Screen: Displays a notification indicating suspicious activity detected.

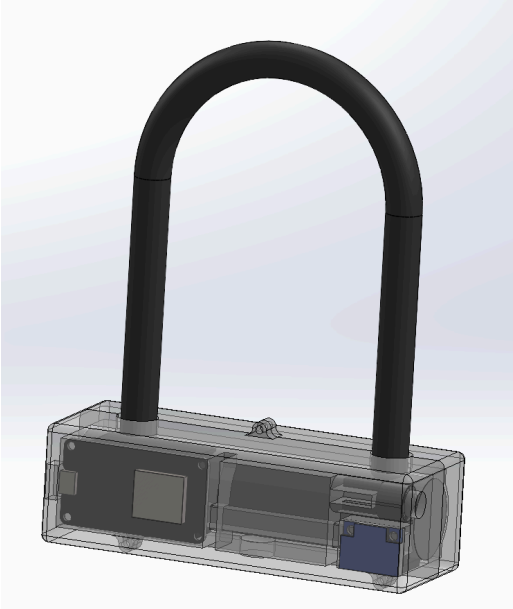
Settings Slider: Allows users to pair a new lock or logout.

Map Slider: Shows the location of the bike on a map.

Notification Slider: Provides details of suspicious activity detected.

Diagram 3: 3D Model of Smart Bike Lock

The third diagram is a 3D model of the smart bike lock. It visually represents the lock's hardware components, including:



The main lock body with internal components.

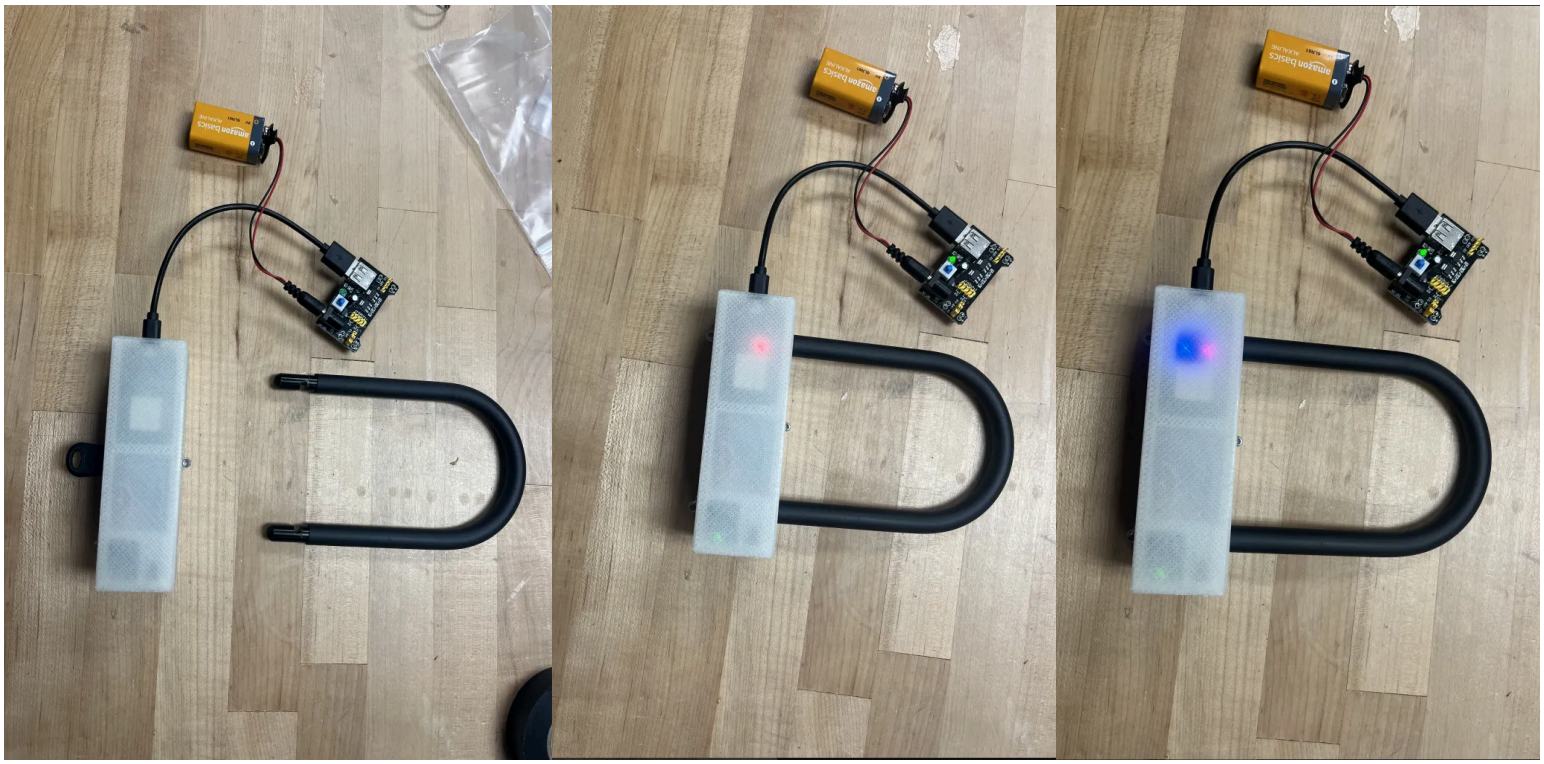
The shackle that secures the bike.

Internal compartments housing the ESP32, Accelerometer, and Buzzer for the alarm along with space for a battery.

Diagram 4: Prototype of Smart Bike Lock

The fourth diagram depicts our MVP of the smart bike lock. It includes:

- The assembled lock with visible LED indicators (red light is on, blue light is armed).
- An external battery pack connected to the lock as this is a temporary solution for the MVP



Accessibility Factors

The design choices for our smart bike lock's UI were meticulously made to ensure accessibility for users with visual or motor impairments. We prioritized a clean and intuitive layout with large, easily tappable buttons and high-contrast colors to enhance readability and usability. Each screen

features clear, simple icons and minimal text to reduce cognitive load, making navigation straightforward. Key actions, such as locking and unlocking the bike, are prominently displayed and easily accessible, ensuring that users can quickly perform essential tasks. By adhering to these design principles, we aimed to create a user interface that is not only functional but also inclusive, providing a seamless experience for all users regardless of their accessibility needs.

KANO Model

The KANO model helps categorize product features into three main categories: Must-haves, Performance needs, and Exciters/Delighters. Here's how we can apply it to our smart bike lock:

Must-Haves

These are the essential features that the product must have to meet basic customer expectations. Without these, customers would be dissatisfied.

1. Must Actually Secure the Bike Well: The primary function of the lock is to secure the bike. This includes physical robustness and resistance to common tampering methods.
2. Secure in Relation to Competitive Price Points: The lock needs to offer a level of security that is competitive with other locks in the same price range. This ensures customers feel they are getting value for their money.

Performance Needs

These features enhance customer satisfaction proportionally—the better they are, the more satisfied customers will be.

1. Easy to Use: Both the physical lock and the mobile app should be user-friendly. This includes intuitive design, straightforward locking and unlocking mechanisms, and easy-to-navigate app interfaces.

2. Real-Time Notifications: The lock should reliably send real-time notifications to the user's phone when tampering is detected. This feature should work seamlessly and consistently.

Exciters/Delighters

These are features that go beyond customer expectations and can significantly increase satisfaction when present.

1. Connects to Your Phone to Alert You of Tampering: Integration with a mobile app that provides real-time alerts and updates about the bike's status. This feature offers peace of mind and convenience.
2. Sets Off an Alarm to Scare Off Thieves: The lock emits a loud alarm when tampering is detected. This acts as a deterrent and provides an immediate response to theft attempts.

Iterations

Hardware Iterations

Our smart bike lock has undergone several significant hardware iterations from its original concept to the current MVP. Initially, our design included a comprehensive set of features aimed at maximizing security and convenience for users. The original design comprised the following components:

1. Motion Detection and Tampering Wire: The lock was equipped with an accelerometer to detect motion and a wire running through the shackle to detect tampering attempts.
2. SIM Card for Notifications: This feature was intended to send real-time messages and notifications to users via a SIM card.
3. Speaker/Buzzer Alarm: To deter theft, the lock included a speaker or buzzer that would emit a loud alarm when tampering was detected.

4. Rechargeable Battery and Solar Panel: The lock featured a rechargeable battery supported by a solar panel to maintain the battery charge.

However, due to time constraints and the complexity of integrating all these components into the MVP, we had to simplify the design significantly. The major changes made for the MVP include:

Bluetooth Connectivity: We opted to use Bluetooth instead of a SIM card for connectivity, reducing the complexity of the design and focusing on core functionality.

Focus on Motion-Based Detection: The shackle wire was dropped, and the emphasis was placed on the motion-based tampering detection system to ensure reliability.

Removal of Rechargeable Battery and Solar Panel: To streamline the design and focus on essential features, we removed the internal rechargeable battery and solar panel.

Dropped App Locking/Unlocking Feature: Due to time and security concerns, we decided to forgo the app-based locking and unlocking functionality for the MVP.

In terms of accessibility, we reasoned that those who are unable to use our physical bike lock are likely not legally allowed to ride a bike, thus simplifying our target user base. Moving forward, we aim to reintroduce and enhance these initial features as part of our final design, potentially expanding the product line to include different types of locks (e.g., chain locks) and added functionalities (e.g., app-based locking/unlocking).

Software Iterations

The software component of our smart bike lock also evolved alongside the hardware changes. Initially, the software was designed to handle Bluetooth communication using specific libraries.

However, as we plan to transition from Bluetooth to cellular connectivity in future iterations, significant changes are required in the software architecture.

From Bluetooth to Cellular: The original Arduino code utilized the BLEDevice.h and BLEServer.h libraries for Bluetooth communication. To accommodate the transition to cellular connectivity, we will replace these with the TinyGsmClient.h library.

Real-Time Notifications: The software will need to adapt to handle real-time notifications via cellular networks, ensuring that the system remains responsive and reliable.

Scalability and Flexibility: The codebase must be scalable to integrate additional features in the future, such as app-based locking/unlocking and enhanced security protocols.

By focusing on these iterative improvements, we aim to ensure that our smart bike lock not only meets the immediate needs of our users but also evolves to incorporate advanced functionalities and greater reliability in subsequent versions.

Identification and Discussion of RATs (Riskiest Assumption Tests)

Riskiest Assumption Tests (RATs) are critical to identifying and validating the core assumptions that must hold true for the success of our smart bike lock. Here are the primary RATs for our product:

1. Technological Challenges

Assumption: The Bluetooth connectivity will be reliable for real-time notifications.

Test**:** Conduct extensive field testing to ensure that the Bluetooth connectivity remains stable and reliable in various environments, such as urban areas with potential signal interference.

Validation**:** Success is measured by the consistent delivery of notifications without delays or missed alerts.

Risk Mitigation**:** If Bluetooth proves unreliable, we may need to expedite the transition to cellular connectivity or explore other communication technologies.

2. Product-Market Fit

Assumption: There is sufficient demand for a smart bike lock among college students and urban cyclists.

Test**:** Perform market surveys and pilot programs on college campuses and urban areas to gauge interest and gather feedback.

Validation**:** High levels of interest and positive feedback from potential users, leading to a significant number of pre-orders or early sales.

Risk Mitigation**:** If demand is lower than expected, we may need to adjust our target market or refine the product features to better meet user needs.

3. Cost Assumptions

Assumption: The $40-50 price point with a $7 monthly subscription is acceptable to our target market.

Test**:** Conduct pricing experiments, such as A/B testing different price points and subscription models, to determine the most acceptable and profitable pricing strategy.

Validation**:** Achieving a balance where the majority of potential customers are willing to purchase the lock and subscribe to the service.

Risk Mitigation**:** If the current pricing model is rejected by users, consider alternative pricing strategies, such as a higher upfront cost with a lower subscription fee or offering discounts for students.

4. Customer Assumptions

Assumption: Customers value real-time tampering alerts and alarm features enough to switch from traditional locks.

Test**:** Gather user feedback through interviews and surveys, focusing on the importance of real-time alerts and audible alarms.

Validation**:** Positive feedback indicating that these features are significant motivators for switching to the smart lock.

Risk Mitigation**:** If customers do not find these features compelling, explore additional features or enhancements that could increase the product's value proposition.

5. Usability

Assumption: The smart bike lock and its app are user-friendly and easy to set up and use.

Test**:** Conduct usability testing with a diverse group of users to identify any pain points or difficulties in setting up and using the lock and app.

Validation**:** Users can set up and use the lock and app with minimal assistance, and feedback indicates high satisfaction with the user experience.

Risk Mitigation**:** If usability issues are identified, prioritize iterative improvements based on user feedback to enhance the overall user experience.

6. Security

Assumption: The smart bike lock provides sufficient security to deter theft and tampering.

Test**:** Simulate various tampering and theft scenarios to test the lock's robustness and the effectiveness of its alarm and notification system.

Validation**:** The lock successfully deters tampering and theft attempts in the majority of test scenarios.

Risk Mitigation**:** If security vulnerabilities are discovered, enhance the lock's physical and software security measures to improve resilience.

By conducting these RATs, we can validate the critical assumptions underpinning our smart bike lock's success. The insights gained from these tests will inform necessary adjustments to our MVP or overall product strategy, ensuring that we deliver a product that meets user needs and performs reliably in the market.

7. Cost and Revenue Models

Type of Business

Our business model is primarily B2C (Business to Consumer), targeting individual bike owners, particularly college students and urban cyclists, who are looking for enhanced bike security

solutions. Additionally, we have a B2B (Business to Business) component, where we market and sell our products to bike rental and tourism companies, as well as bicycle retail stores. This dual approach allows us to tap into both direct consumer sales and bulk purchases by businesses that can benefit from offering our smart bike locks to their customers.

Customer Acquisition Cost (CAC):

CAC is the total cost associated with acquiring a new customer, including marketing, sales, and other expenses. For our smart bike lock, the CAC includes:

1. Marketing Expenses: Costs related to digital marketing campaigns, social media advertising, influencer partnerships, and campus events.
2. Sales Expenses: Costs associated with sales personnel, promotional materials, and distribution.
3. Customer Support: Initial customer support and onboarding costs to ensure a smooth setup and positive user experience.

$$\text{CAC} = \frac{Total\ Marketing\ and\ Sales\ Expense}{Number\ of\ New\ Customer\ Acquired}$$

Lifetime Value (LTV):

LTV is the total revenue expected from a customer over the entire duration of their relationship with our business. For our smart bike lock, LTV includes:

1. Initial Product Purchase: Revenue from the initial sale of the bike lock, priced at $50.
2. Subscription Revenue: Ongoing revenue from subscriptions, either $7 per month for cellular services or $15 per month for cellular services plus replacement parts.

To calculate LTV:

LTV = (Average Purchase Value + (Subscription Fee × Months of Subscription)) × Customer Lifespan (in years)

Assuming:

- The average customer subscribes to the $7 monthly plan.
- The average customer lifespan is 3 years.

LTV= $50 + ($7×12×3) = $50 + $252 = $302

Analysis

The relationship between CAC and LTV is critical for ensuring business profitability. Ideally, the LTV should be significantly higher than the CAC to ensure that the cost of acquiring a customer is justified by the revenue generated from them over time.

Strategies to Optimize CAC and LTV

1. Reduce CAC:

    Leverage cost-effective marketing channels like social media and referral programs.

    Optimize ad spend through targeted advertising and data-driven campaigns.

    Increase organic reach through content marketing and SEO.

2. Increase LTV:

    Enhance customer retention through excellent customer service and continuous product improvements.

    Upsell additional services or products, such as premium subscriptions or accessories.

    Implement loyalty programs to encourage repeat purchases and long-term subscriptions.

By carefully managing and optimizing both CAC and LTV, we can ensure sustainable business growth and profitability.

Discussion of Business Growth and How These May Change

In the initial growth phase, our primary focus will be on college students and urban cyclists, who are likely to benefit most from our smart bike lock. To build a strong customer base, we will implement targeted marketing strategies such as campus partnerships, social media campaigns, and local events. Our main revenue streams in this phase will be from the sale of the smart bike lock at $50 and the subscription service for cellular connectivity at $7 per month. Additionally, offering a higher tier subscription at $15 per month, which includes replacement parts, will cater to customers seeking extra value and convenience. Cost-effective marketing channels and optimizing our customer acquisition cost (CAC) will be crucial in the early stages, with referral programs and partnerships with cycling clubs helping to reduce acquisition costs.

As we gain traction, we will enter the expansion phase by introducing new products and features, such as chain locks and app-based locking/unlocking functionality. This will help attract a broader customer base and increase revenue per customer. Geographic expansion will follow, targeting other bike-friendly cities and regions, with marketing efforts tailored to the unique characteristics and needs of each new market. We will also expand our focus to include business-to-business (B2B) sales, marketing to bike rental and tourism companies as well as bicycle retail stores. Offering bulk purchase discounts and customized solutions for businesses can provide a stable and significant revenue stream.

In the mature growth phase, we will invest in research and development to enhance the product's technological capabilities, such as transitioning from Bluetooth to cellular connectivity for more reliable real-time notifications. Incorporating additional security features and integrating with smart city infrastructure will further differentiate our product in the market. Implementing loyalty programs and providing excellent customer service will maintain high customer retention rates. Regular updates and improvements based on user feedback will sustain customer satisfaction and loyalty. As the business grows, optimizing operations and supply chain management will be essential to maintain profitability. Leveraging economies of scale will help reduce costs and improve margins.

The market dynamics will change over time, and staying agile and responsive to these changes will be crucial. Continuous market research and adapting our product and marketing strategies accordingly will help maintain relevance and competitiveness. We will keep abreast of changes in regulations related to consumer electronics, data privacy, and transportation to ensure

compliance and avoid potential legal issues. Monitoring competitors and differentiating our product through unique features and superior user experience will be key to sustaining growth. Strategic partnerships and alliances can help strengthen our market position and provide additional growth opportunities.

By focusing on these growth phases and adapting to changing dynamics, we can ensure sustained business growth and long-term success in the market.

8. Traction to Date

Our current iteration of the MVP has the communication system set up with our lock in a housing unit that fits around a U-lock, and an accelerator with our ESP32 to communicate with our app. So all of this shows the viability of our product and that the technology is easily doable for us. Going forward there are many improvements we have outlined to take it to the next level. For instance to test the casing we created for our components was created using 3d printing with plastic. Obviously for future iteration it would be a metal encasing and with a good manufacturing team it can actually be integrated into the shackle itself to make it more ergonomic. This will also increase its security which is important. Currently our wireless connection is done through bluetooth low energy. This is great for demonstration purposes but going forward switching this communication to using a Sim card for very long range connection and communication with the device. This way users can stray from their bike a reasonable distance and still have it communicate if there is tampering detected. We also have quite a low output buzzer associated with the device so this would be interchanged with something that has a high 80+ decibel rating in order to be an effective deterrent. Despite there being a lot of hardware upgrades that need to take place we have designed our product so far that each module that needs

to be replaced can be done easily and not affect the rest of the system. A process like this allows us to consistently make necessary changes so that we can continue to expand on our ideas without there being large amounts of technical debt involved, especially as the project continues further. The other side that would be upgraded especially when being brought to scale is our app. Making sure the app can run on different devices will be important as well as having support for the business model discussed in selling to rental companies where the company can have control over the bike locks as well to keep tabs on all of their locks and bikes rather than just the individual user experience. Going forward with customers during interviews many people expressed interest in there being more products beyond just the bike lock that had smart features. So continuing to interview these customers on wants contains a lot of potential for moving forward. Connecting with rental businesses is also a more complex task that we can invest time into. All in all a prototype with all basic features exists to show off its functionality.

9. Project Review

Creating this smart bike lock product wasn't an easy task, it required us to think outside the box and learn how to work together. We all have different skill levels for specific tasks so we assigned people to the task they are most familiar with and interested in. David Park is the most experienced with hardware as he is an Electrical Engineering student and has experience with laser cutting and 3D printing. Marc Reta and Declan Bohley are the most experienced with the backend such as being fluent in Python, FastAPI, and Javascript due to taking classes such as CSE 110 and ECE 141A. Taimur Shaikh is the most experienced with the frontend as he has designed his own app before. This means that we all have very specific skills that we're proficient in which makes it much easier to split up the work. Since David is the most experienced with hardware, he was in charge of measuring each hardware component and

creating the stereolithography files which can be used to 3D print the housing unit shell of our smart bike lock. Since Marc and Declan are the most experienced with the backend, they were in charge of creating the Arduino code for ESP32 which determines how it communicates with the buzzer and accelerometer and how it uses bluetooth to communicate with the website application. They were also in charge of creating the routes to the html page through FastAPI and the javascript code which helps communicate with the ESP32 through bluetooth. Since Taimur is experienced with software, he was in charge of designing our website application using CSS and HTML. All of these tasks are important because the housing unit shell will store all of our hardware modules (such as the ESP32, buzzer, accelerometer, and U-lock), the Arduino and Javascript code is essential for the ESP32 to communicate with the hardware modules and website application, and the design of our website application will affect how accessible our product is to many different types of consumers.

Throughout this project, we had some hurdles to overcome in order to reach our goal of creating our first prototype. One problem that we encountered was the huge difference between all of our schedules which made it difficult to meet and discuss what we had to do. This required us to communicate more on discord to make sure everyone was on the same page and doing the tasks they were assigned for during the sprint. Another problem that we encountered was that 3D print takes a huge amount of time, sometimes lasting up to 6 hours, which means that if there is a slight mistake with how ESP32 and the hardware components fit into the 3D print, we would have to restart the print which can take another 6 hours. Since everyone has their own expertise on the specific part of the project, it can be a blessing and a curse. It could be a problem if one of us get sick. Unfortunately, David got really sick near the end of quarter and the rest of us didn't know how to create the stereolithography files to 3D print which delayed progress with our

prototype. This situation highlighted the importance of cross-training and having a backup plan in place for critical roles. In addition, with the ESP32 and the hardware modules, we had problems with the connections with the wires that connects them all. Our jumper wires were very loose and once it slightly moves away from the ESP32, buzzer, or accelerometer, our product would not work. This was a huge challenge for us since the wires slightly disconnecting wasn't noticeable. We initially thought it was a problem with our Ardurino code until we looked very closely with our ESP32. As a result, we replaced all of our jumper wires with more secured ones and added tape to make sure all the wires doesn't disconnect. Additionally, our reliance on discord sometimes led to misunderstandings and miscommunications, which we had to address by implementing more frequent check-ins. Despite these challenges, we remained resilient and adaptable, demonstrating strong problem-solving skills and teamwork.

We also had many successes with our project. Despite the many setbacks we experienced, we were able to work together to finish creating our first prototype. Some of our successes is that each of us were able to complete the tasks we were assigned to us for each sprint and we were open to feedback from each other. We created a safe space where everyone was comfortable to give criticism to improve our product. We found that clear communication is very important since it allows us to be clear with each other about what we expect by the end of the week and how to improve our workflow. We also found the GitHub Project Page to be significantly helpful for managing our project as it allows us to keep track of what tasks that still need to be done for the current sprint and who are assigned to the specific task. In addition, using the GitHub Project Page facilitated transparency and accountability within the team, as everyone could easily see progress and updates. This tool also helped in identifying any bottlenecks early, allowing us to address them promptly and keep the project on track. Another key success was our ability to

leverage each team member's unique strengths, which led to us learning from each other. For Marc and Declan, they implemented a technique called pair-programming where one person is the one typing the code and the other person is the one watching and spotting for any mistakes. This was very useful as it not only reduced the number of errors but also enhanced their coding skills through collaboration and immediate feedback. Pair programming also fostered a deeper understanding of each other's approaches and techniques, leading to more cohesive and high-quality code. In addition to pair programming, we also implemented regular code reviews where the entire team could provide input and suggestions. This collective approach ensured that our codebase remained clean, efficient, and aligned with the best practices. As a result, this proactive attitude towards learning and self-improvement contributed significantly to the overall success and quality of our prototype.

10. Accessibility and Ethical Considerations

With the creation of our smart bike lock product, we also have to think about the many accessibility and ethical concerns that come with the use of bluetooth, the design of our bike lock, and the use of our own website application. There are many people who might have physical limitations, such as weaker bones, so it was important to us to make sure that our bike lock is lightweight and not overly bulky, and that our smart hardware features don’t make the lock harder to attach to the bike. We also made sure that our lock is easy to use by using a physical key to unlock and lock the bike. This allows the user to not worry about the lock mechanism not working properly due to a bluetooth connection error. Our bike lock only uses bluetooth for our smart features such as movement detection and alarm.

In addition to the hardware, we also had to make sure that our software user interface was accessible to all types of users by designing our interface to have clear words such as “Bike is

safe” and “ALERT!” when the bike is being tampered with. Our words are short and straight to the point to avoid unnecessary confusion and the words appear at the top of the screen which is easy to see by the user. Since our primary notification method involves sound through our buzzer, providing an alternative form of notification through our website application is very crucial. As a result, when the bike is being tampered with, our javascript code will send a notification alert that says “ALERT!” to the user and when the user enters the app, there will be a section of the screen dedicated to the state of the lock which will say whether the bike is safe or being tampered with. Our website also contains only 2 buttons which are the on and off buttons for our alarm. The reason why we did this design is to keep our website design simple and not convoluted. This makes our website design more user-friendly for children or the elderly as they might have different levels of tech-savviness and physical capability.

We also had to think about potential users who would have visual impairments. In order to accommodate their needs, our website application incorporates high-contrast color schemes, and every section of our website application is clearly labeled including our 2 buttons which let the user arm and disarm the alarm. These buttons are also designed to be prominently placed in the middle of the page, ensuring they are easily accessible. In addition to these buttons, our website application also has each section labeled with bold letters which helps people with visual impairments tell which section they want to look or tap in.

Another potential scenario that we have to worry about is the community's reaction to our alarm system. As developers of the alarm system included in WheelWatch, we have to make sure that there are no false alarms that happen when there is no one tampering with the bike. Regular false alarms could lead to a "cry wolf" scenario where people start ignoring the alarms, reducing their effectiveness. In order to tackle this issue, we made sure to do rigorous testing where we

tested the specific values we got from our accelerometer and only made the buzzer go off when it reached a certain threshold. When the difference between the initial value and the upcoming value from our accelerometer is more than 1, we set the buzzer to go off. We tested different numbers and found that 1 is the best difference between the initial and upcoming values for our use case.

With the use of bluetooth, we have the ability to gather a lot of sensitive data from our users such as location and messages. This requires us to be mindful of the things we do with bluetooth in our product. Fortunately, we only used bluetooth to connect to the device and send notifications to notify the user that their bike is being tampered with and allow the user to arm and disarm the lock. This also means that we do not collect, store, or transmit any additional data through our bluetooth connection. We find it important that we only use the data necessary to arm and disarm the alarm. We do not track users' locations, access their messages, or gather any other personal information since it doesn't benefit the task of sending notifications and allowing the users to arm and disarm the alarm.

We also thought about the accessibility issue related to cost which is one of the reasons why we chose to use a sim card for our future implementation of our product (Bluetooth is only temporary to show functionality). With the use of a sim card, users are able to choose any cellular carrier of their choosing. Currently, there are ways for consumers to get a cellular plan as low as $15 a month through a cellular carrier called Mint Mobile or even as low as $5 a month through a cellular carrier called Tello. By providing users with the ability to choose, they have the option to pay the amount they feel comfortable with.

Overall, it is important for us to be very accessible to a wide range of consumers. We prioritized accessibility and ethical considerations by designing a lightweight, easy-to-use

product that accommodates users with physical limitations, visual impairments, and varying levels of tech-savviness. We ensured reliability through a physical key mechanism, high-contrast visual cues, clear notifications, and a simple user interface with only essential buttons. Our rigorous testing minimizes false alarms, preventing community desensitization. Ethically, we respect user privacy by limiting Bluetooth use to necessary functions without data collection, and future plans include affordable cellular options to enhance accessibility. Our comprehensive approach aims to make our smart bike lock user-friendly, reliable, and inclusive for a diverse range of users.