ME553 - Product and Process Design

A5 - Product Prototyping and Implementation

Group Project: TEAM_ONC_5

(Andrew, Savani, Gokul, Abhishek)

Deliverables required:

The list of deliverables for A5 are provided in the assignment.

1. Detailed sketches of the final concept.

2. CAD models showing all product functions.

3. Usage Scenario Description – a storyboard to convey how the product should be used.

4. Prototype (low-fidelity physical mock-ups – need not be fully functional) a. Additional info below.

~~**Product Service Models**~~ **(for service-based products) (Not applicable to our product)**

5. User-Study (use of the prototype to obtain user feedback)

6. Preliminary Business Model Design (right side of the canvas, see example below)

7. Assessment of risk and scope for Further Improvements.

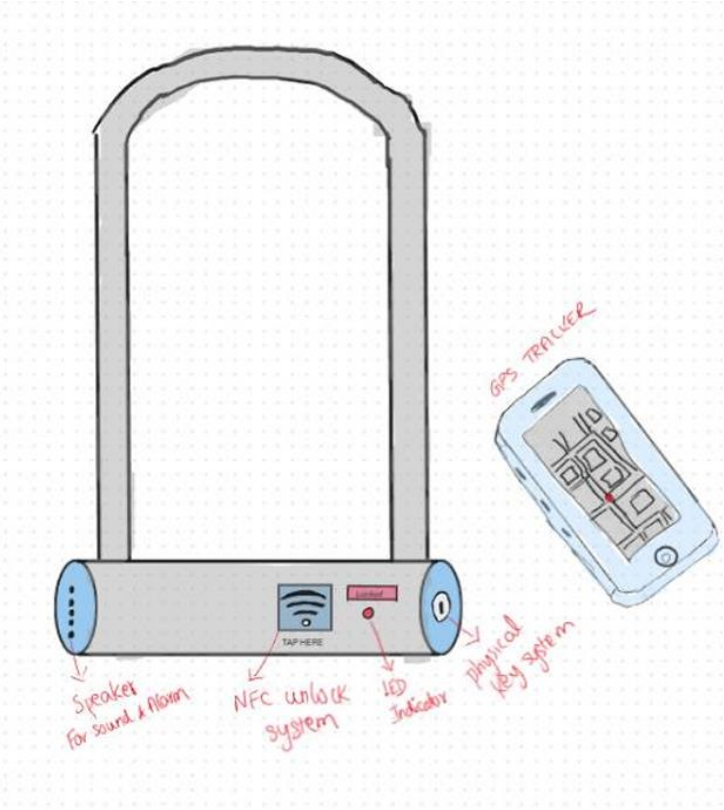
8. Consideration of the feasibility and viability of the product in terms of its production, product-market fit, and competition.

9. If you were to design your product using the principles of Circular-Design, what would you change and how?

Title:
"TAP TO UNLOCK LOCK SYSTEM FOR BICYCLE LOCKS (NFC Based Unlocking System)"

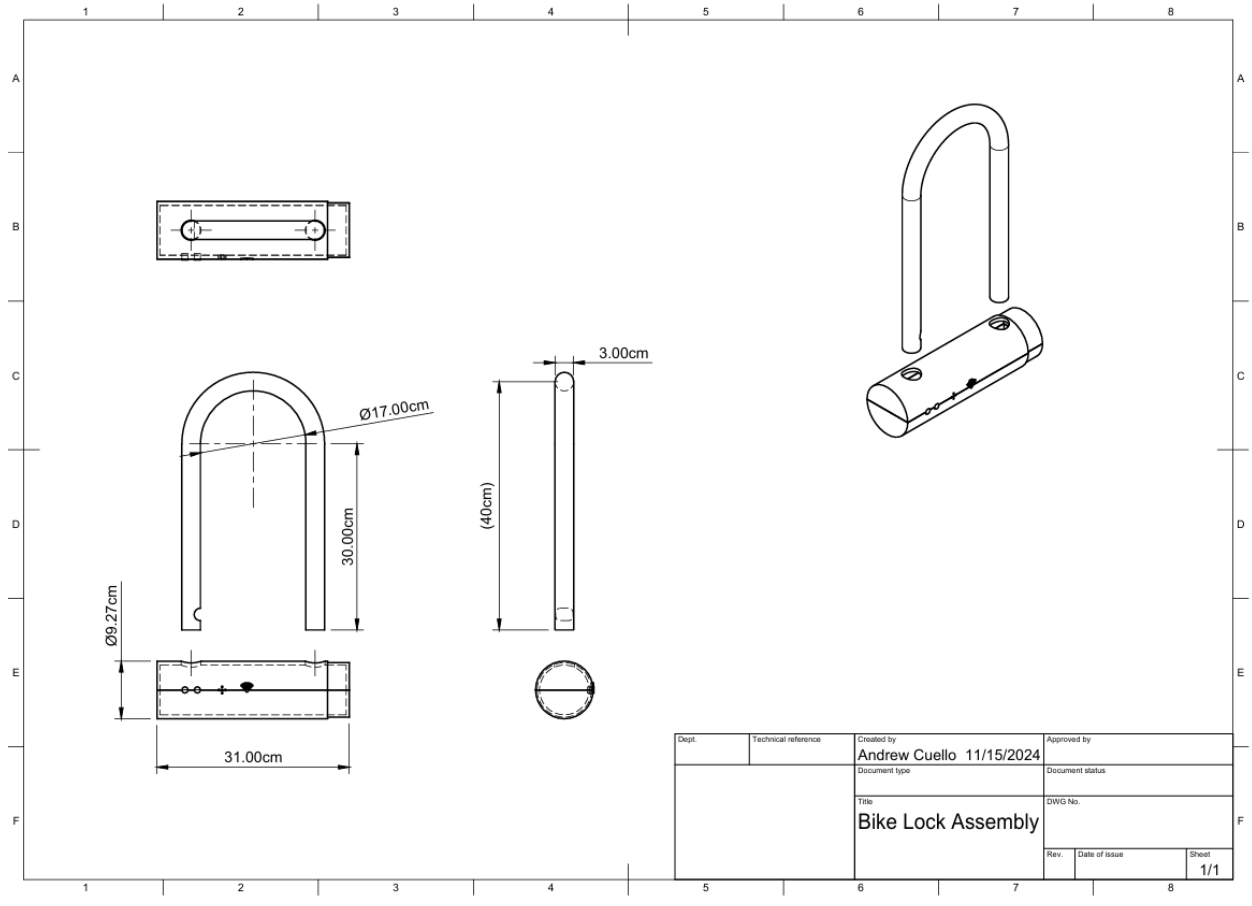
ANSWER:

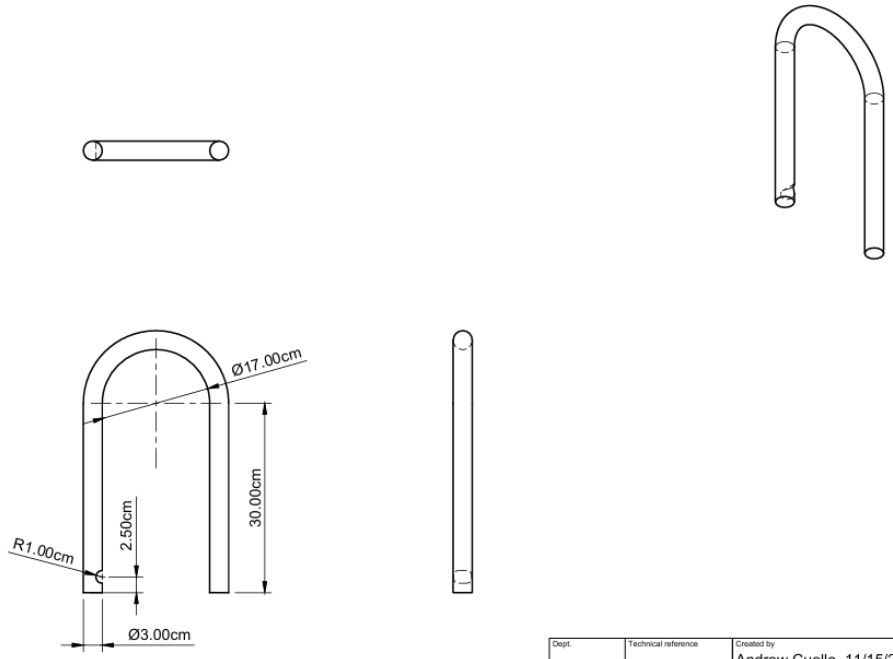
1. ***Detailed sketches*** of the final concept.



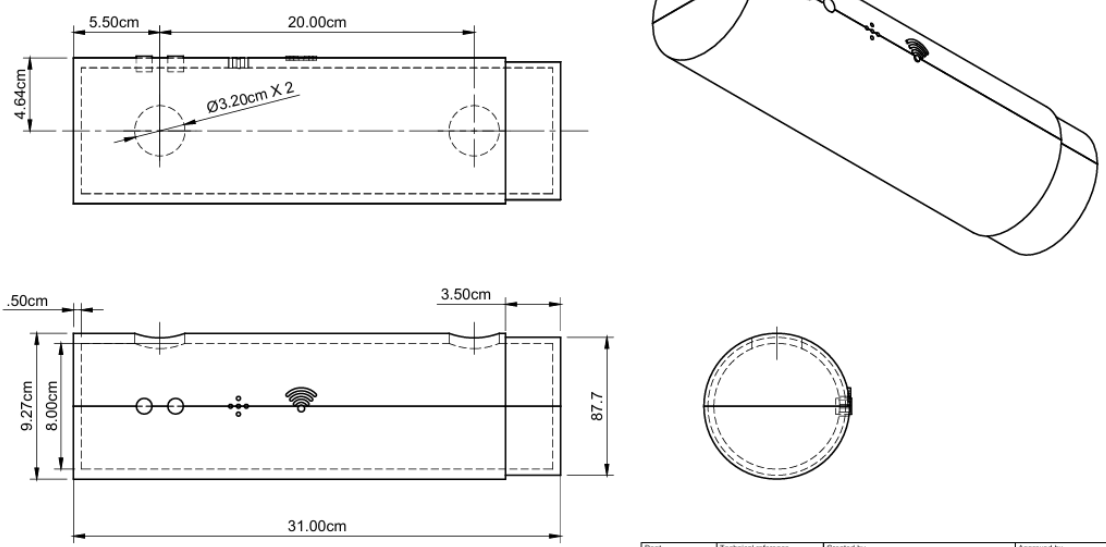
This hand-drawn sketch is of our prototype to our **Smart Bike Lock** device. It highlights and points out key features and functionality of the device. Below are CAD sketches of the device with detailed dimensions as well as indicates how the device would be manufactured and how its parts can be broken up.

CAD Drawings:





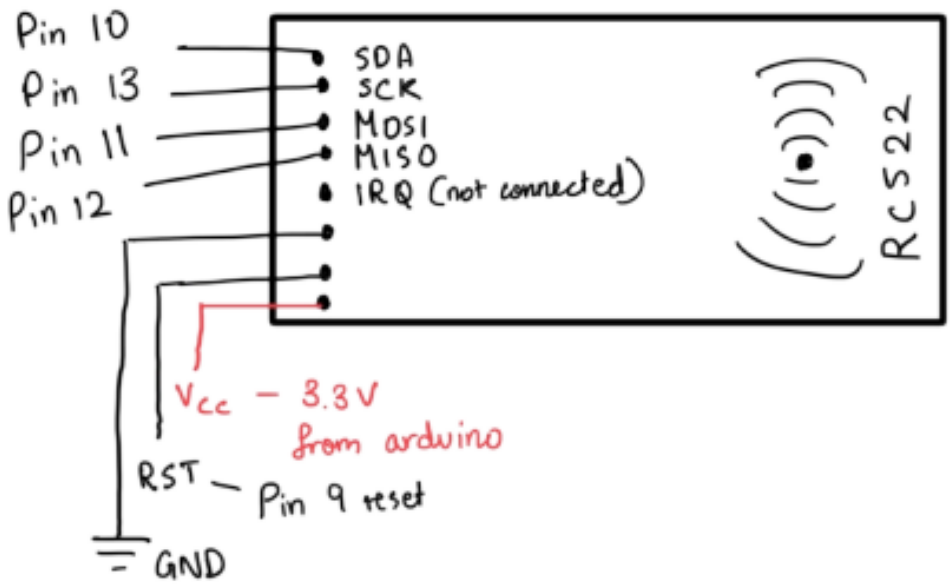
Dept.	Technical reference	Created by	Approved by
		Andrew Cuello 11/15/2024	
		Document type	Document status
		Title: U-Lock	DWG No.
			Rev. / Date of issue / Sheet: 1/1



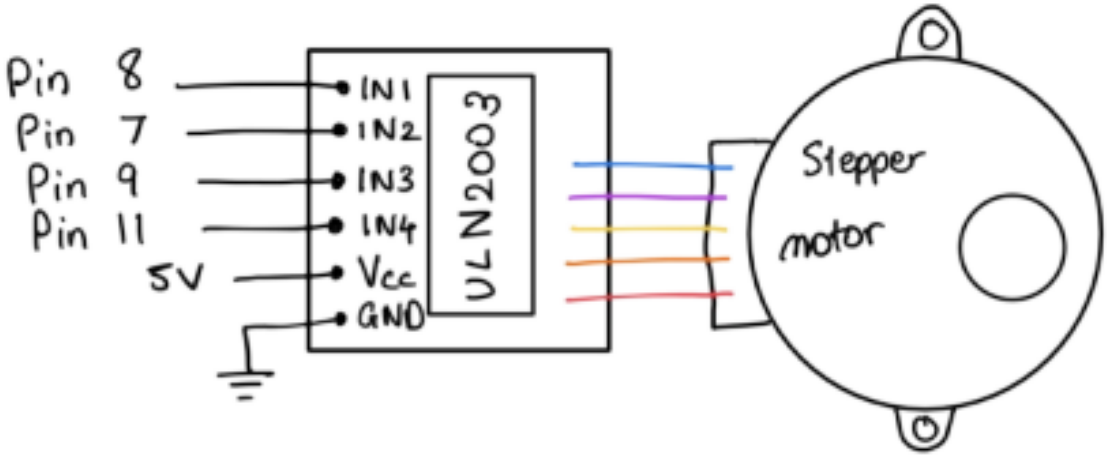
Dept.	Technical reference	Created by	Approved by
		Andrew Cuello 11/15/2024	
		Document type	Document status
		Title: Smart Casing	DWG No.
			Rev. / Date of issue / Sheet: 1/1

Circuit Design:

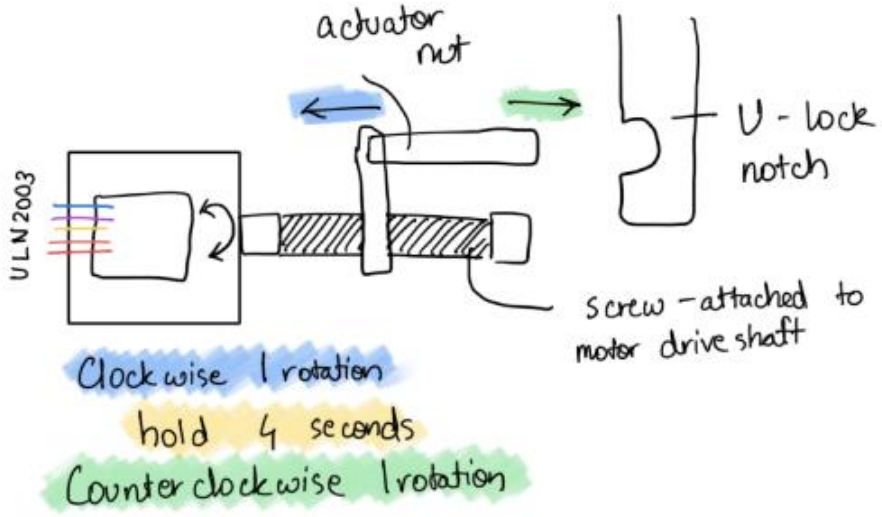
RFID Module Circuit:



Stepper Motor/ULN2003 Circuit:

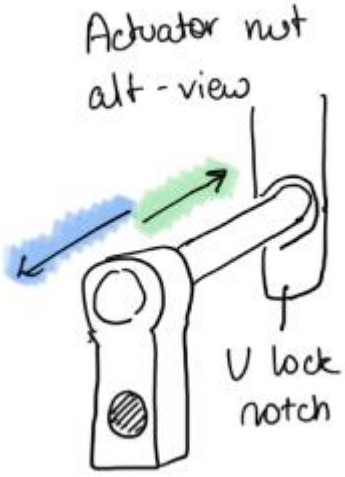


Actuation Mechanism:



Clockwise rotation moves actuator nut away from U-lock

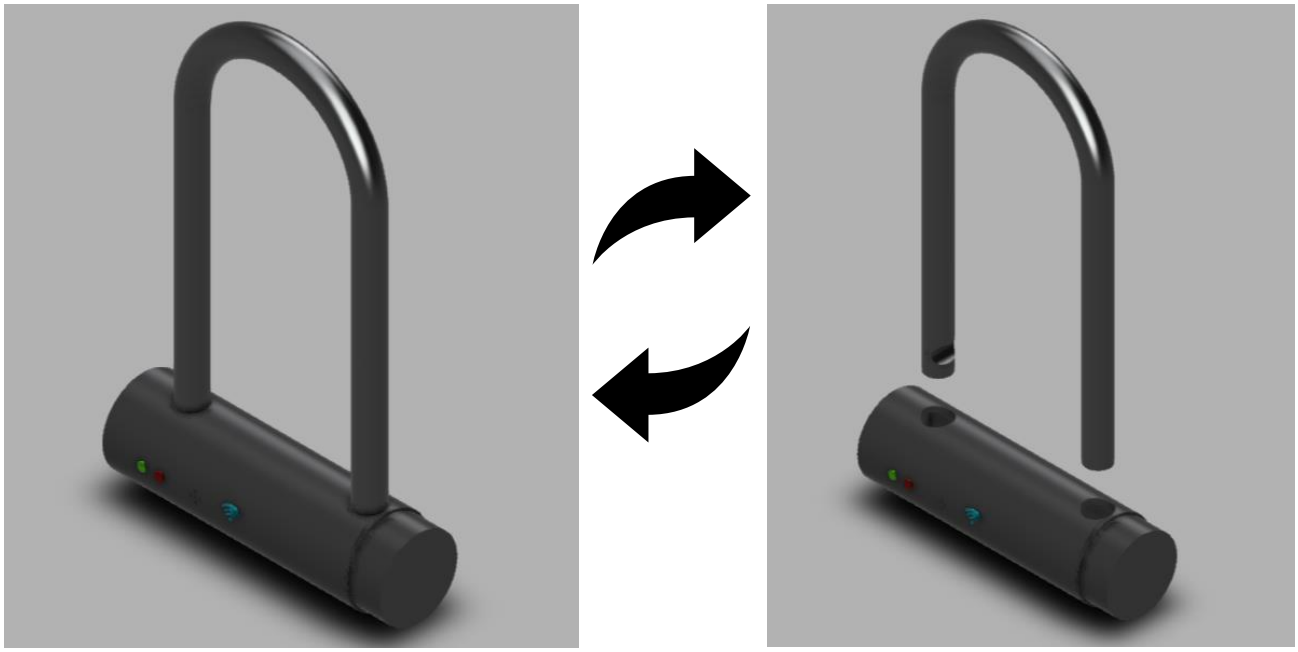
Counterclockwise rotation moves actuator nut towards U-lock



This product design has been crafted to meet customer needs for convenience, security, and reliability effectively. Featuring a feedback LED indicator system, it provides clear, immediate visual feedback: a red light signifies the lock is engaged, while green indicates an unlocked state. This design also includes auditory feedback through a compact speaker on the side of the lock, adding an extra layer of user awareness upon lock and unlock actions. A signal is also sent to user devices to inform them of the lock's status, ensuring users are always informed and alert of their bike's safety The primary unlocking method is a wireless "Tap to Unlock" NFC system, enabling

seamless access via smartphone wallets, such as Apple Wallet. To ensure reliability, especially in unexpected situations, the lock includes a backup physical key system. The motor-driven locking mechanism ensures secure, consistent operation, and an integrated anti-theft feature activates a high-volume alarm if tampering is detected. The device is physically locked through an actuator nut holding the U-lock in place through a motor. For enhanced tracking and peace of mind, this design incorporates an Air Tag, allowing users to monitor the lock's location via GPS. Together, these features make this lock an effective, all-encompassing solution, crafted to satisfy and exceed customer expectations for modern security needs.

2. ***CAD models*** showing all product functions.



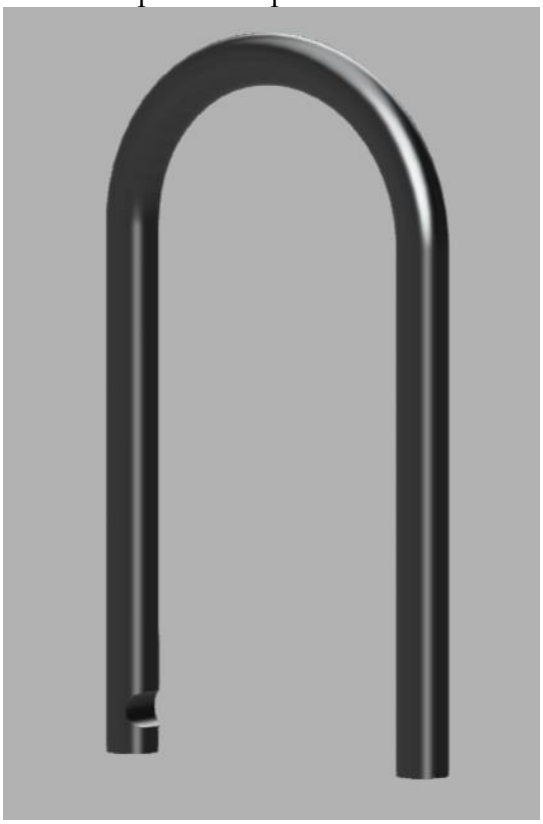
State 1: Secured Locked State

State 2: Secured Locked State

Primary Components

U Lock Shackle:

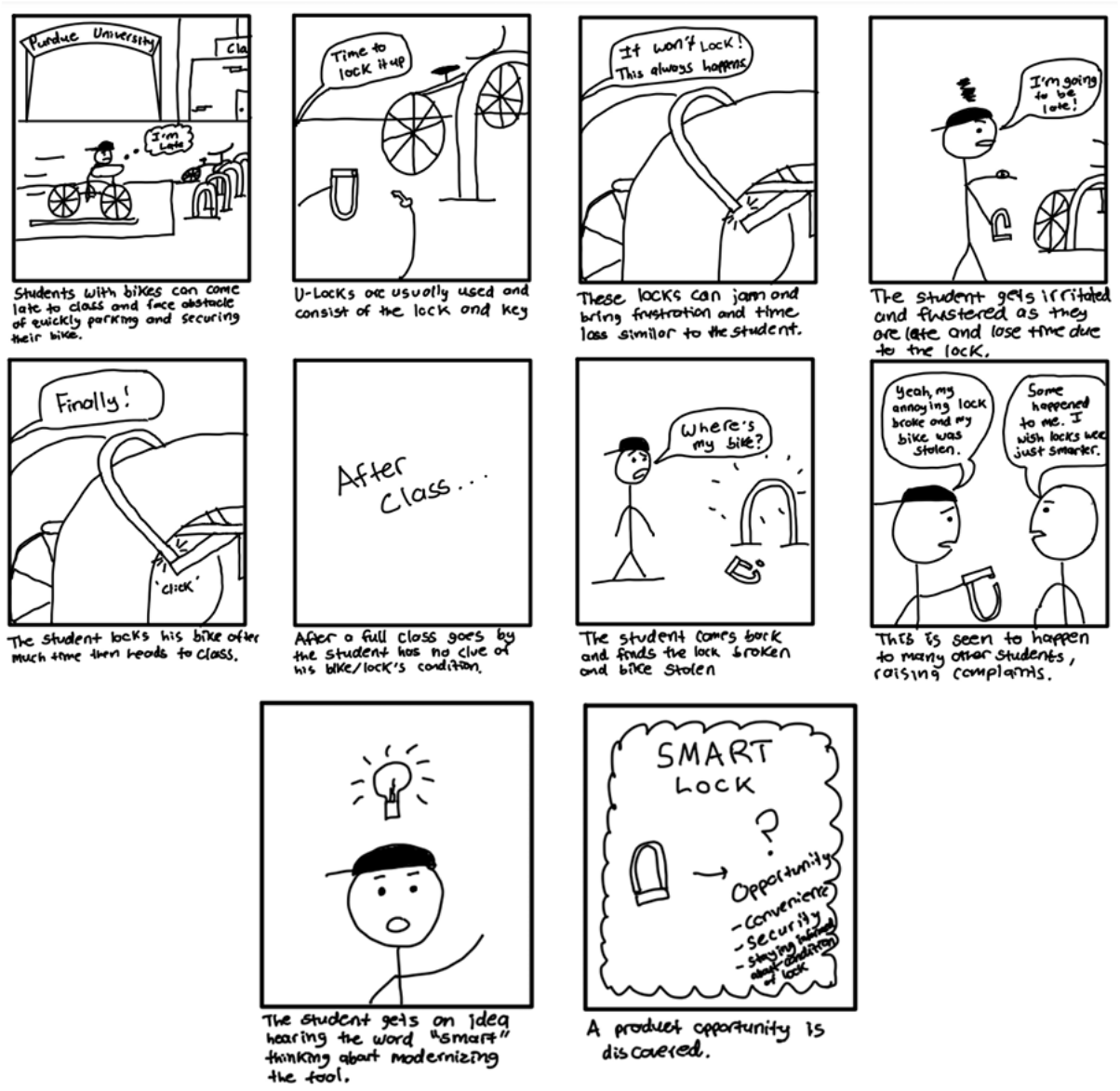
Protective shackle meant to keep bikes and stations secure together. U shape, meant to be like standard Kryptonite bike locks and deter theft. Made of hardened steel or other durable materials to resist cutting, prying, or other forms of tampering. Has a notched end that engages with the base component to secure the piece into place in the base.



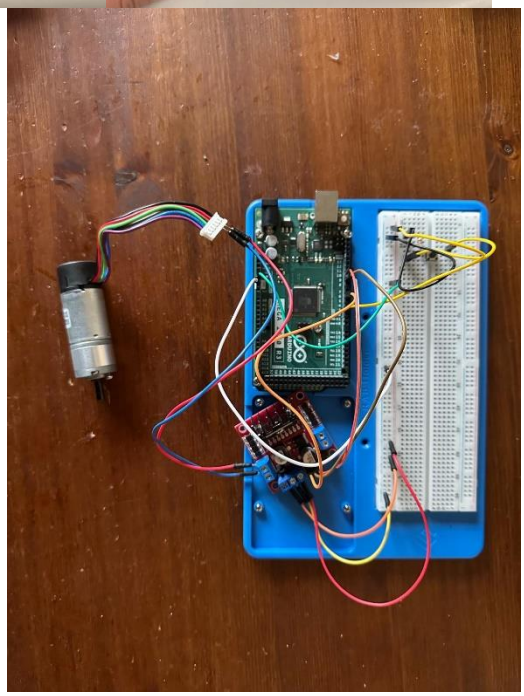
Lock Base:

The base of the lock holds most of the advanced technological components of the device such as the RFID compatibility and its connectivity to a user's device. The piece has two holes in the top that act as openings to secure the shackle. Motors work on the inside to ensure both pieces remain engaged to prevent theft. Small LED lights on the front are used to indicate whether the device is in a locked state.

3. ***Usage Scenario Description*** – a storyboard to convey how the product should be used.



4. ***Prototype*** (low-fidelity physical mock-ups – need not be fully functional)



The CAD files for the Tap-to-Unlock Lock System for Bicycles were 3D printed to conduct a preliminary analysis of the design. During this initial testing phase, issues with the locking mechanism's alignment and fit were identified. These issues were determined to stem from printer tolerancing and kerf width variations in the 3D printing process. Adjustments will be made to the CAD model to account for these tolerances, and a revised version will be reprinted to assess the impact of these modifications. Despite these challenges, the initial prototype is promising, as the locking system demonstrates user-friendly functionality and integrates seamlessly with a bicycle's overall aesthetics.

The primary objective of this prototyping phase was to evaluate the ergonomics and external design of the lock system. Further development phases would delve deeper into the communication between the external shell, the embedded electronics, and the control system. To enhance the functionality of the lock, components such as compact damped servos or rotary potentiometers could be implemented to connect the user interface (e.g., the tap-to-unlock

mechanism) with the internal control system. These additions would enable efficient and reliable communication between user input and the locking mechanism, ensuring smooth operation and enhancing the overall user experience.

5. *User Study*

Using the 3D-printed prototype of our **Tap-to-Unlock Lock System for Bicycles**, we conducted a survey to gather feedback on the design and functionality of the product. We demonstrated the concept, including how the tap-to-unlock mechanism works and the added manual unlocking feature for emergencies. The feedback has been categorized into pros and cons as follows:

Pros:

- Many respondents appreciated the convenience of the **tap-to-unlock feature**, highlighting that it eliminates the hassle of carrying keys while cycling.
- The sleek design was well-received, with users noting that it complements the aesthetics of modern bicycles.
- The inclusion of a **manual key-based unlocking mechanism** was seen as a practical backup in case of technical issues or battery failure.
- Participants liked the idea of a **multi-application lock** system, envisioning its use beyond bicycles, such as in lockers or gym access.

Cons:

- Respondents noted the **lack of LED indicator feedback or sound alerts** for successful or unsuccessful unlocking, which would have improved user confidence during operation.
- Concerns were raised about the lock's **weather resistance**, especially regarding exposure to rain, dust, and temperature fluctuations.
- Some users suggested that the **manual unlocking port** could be better integrated into the design to maintain the lock's sleek appearance.
- A few participants commented that the product might require clear instructions or app-based tutorials for easier setup and operation.

Additional Insights:

- Most users found the concept appealing and were willing to invest in the product in the range of **$60–$120**, depending on additional features like weatherproofing or mobile app integration.
- Suggestions included integrating **future LED or sound systems** to provide feedback, which would enhance usability, especially in low-visibility conditions.
- Several users appreciated the manual unlocking feature but recommended that it be made tamper-proof to enhance security.

  We had included the LED indicator system in the final design but not in this prototype. So in the next prototype we will include these missing. Based on this feedback, the next iteration of the prototype will focus on improving the weatherproofing of the lock, refining the integration of the manual unlocking port, and exploring the addition of feedback mechanisms like LED indicators or sound alerts to elevate user confidence and satisfaction.

6. **Preliminary Business Model Design:**

The right-hand side of the Preliminary Business Model for the **Tap-to-Unlock Lock System for Bicycles** has been developed with long-term sustainability and scalability in mind. Recognizing the current limitations of resources and market presence, the team has outlined realistic short-term goals that will serve as a foundation for achieving the ultimate vision. The following outlines the value proposition, customer relationships, channels, revenue streams, and customer segments.

Value Proposition:

- **Seamless Convenience:** A hassle-free locking and unlocking system that eliminates the need for keys, making bicycle security effortless and intuitive.
- **Enhanced Security:** Advanced locking mechanisms with secure encryption protocols to provide peace of mind to users.
- **Versatility:** Suitable for various applications, including bicycles, lockers, gym storage, and beyond.
- **Durability:** Designed to withstand tough outdoor conditions such as rain, dust, and varying temperatures, ensuring long-term use.
- **Backup Reliability:** Includes a manual unlocking option for emergencies, ensuring consistent functionality even in technical failure or low-battery scenarios.
- **Future-Ready Features:** Scope for integrating app-based functionality, remote control, or multi-factor authentication to enhance the product's utility.
- **Sleek Aesthetics:** Compact and modern design that complements the style of bicycles and other applications.

Customer Relationships:

- Engage customers through regular surveys and feedback loops to refine the product.
- Provide a **user-friendly online platform** for troubleshooting, product guides, and technical support.
- Establish partnerships with cycling communities and influencers to enhance product credibility and reach.
- Offer **bulk deals** to bicycle rental companies or bike-sharing platforms, encouraging long-term partnerships.
- Provide warranties and maintenance plans to build trust and ensure customer satisfaction.

Channels:

- **Online Sales:** A direct-to-consumer model through the official website, providing complete control over the user experience and collecting valuable data for product improvement.
- **Retail Partnerships:** Collaborate with bicycle shops and major retailers (e.g., Walmart, REI) to make the product easily accessible.
- **Collaborations with Bicycle Manufacturers:** Partner with manufacturers to bundle the lock system with new bicycle models as a value-added feature.
- **Campus Programs:** Target university housing and bike-share programs for large-scale installations and contracts.

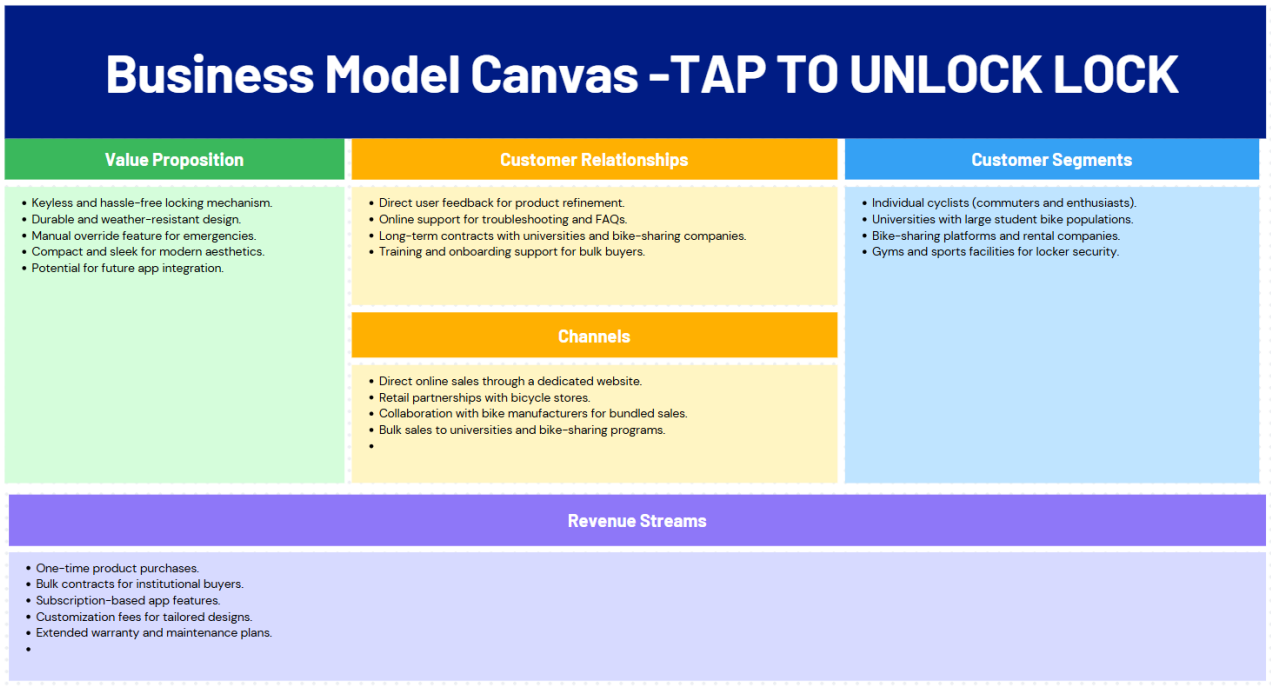
Revenue Streams:

- **One-Time Purchases:** Direct sale of the lock system to individual customers.
- **Subscription Services:** For app-based features like remote lock/unlock, tamper alerts, and advanced analytics.
- **Bulk Orders:** Discounted pricing for large-scale purchases by rental companies, bike-sharing platforms, or universities.
- **Customization Options:** Personalized features or designs for customers willing to pay a premium.

Customer Segments:

- **Individual Cyclists:** People who value convenience, security, and innovation in bicycle locking systems.
- **Bike-Sharing Platforms:** Companies need secure, easy-to-use locking solutions for shared bicycles.
- **Cycling Enthusiasts:** Regular riders or hobbyists willing to invest in high-quality, durable locking systems.
- **Campus Housing:** Universities with extensive bike-use programs could adopt the product for student use.
- **Gym Owners & Sports Facilities:** Locker security solutions for users who bring their bikes and require a secure, integrated lock system.

Business Canvas (Right Side):



Short-Term Goals:

Channels:

- Focus primarily on **online sales** through a dedicated website. This approach allows the team to maintain control over the customer experience, gather valuable feedback, and refine marketing strategies.
- Collaborate with **bike-sharing programs** and **universities** to implement the lock system

on campuses. These collaborations will provide bulk contracts, generate user feedback, and showcase the product's value on a scale.
- Engage with **local bicycle shops** for initial sales to create awareness and establish credibility.

Customer Segments:

- Initially target **bike-sharing platforms**, universities, and other managed-use systems (e.g., gyms or sports facilities). These customers provide opportunities for large-volume contracts and a controlled environment to collect valuable usage data.
- After refining the product based on this feedback, expand to the **individual cyclist segment** for broader market penetration.

Customer Relationships:

- Build relationships with key stakeholders like bike rental companies and university management to streamline communication. These entities act as intermediaries, providing collective feedback for iterative product improvements.
- Focus on **network installations** to understand collective user behavior and address concerns holistically, enabling the team to refine the product effectively.
- Gradually scale customer service capabilities to handle individual users as the product enters the retail market.

By prioritizing these short-term goals, the team can establish a solid foundation for the **Tap-to-Unlock Lock System for Bicycles**, ensuring a sustainable and scalable business model that caters to the needs of diverse user groups.

7. Assessment of Risk and Scope for Improvements

1. Regulation Compliance:

Changing regulations along with non-compliance impact the entire product, when it comes to privacy and safety (GDPR, electronic devices, data protection). Being updated with industry regulations like electromagnetic compatibility (EMC), and other certifications and standards. It is crucial to regularly review data protection and safety laws and guidelines to ensure compatibility. Collaborations and third-party certifications are essential. Product meeting the IP rating along with the periodic audits would help in further reducing the risks.

2. Market Competition:

Intense competition between established players along with new entrants in the digital lock market and smart home gadgets markets could affect the entire market share. Focusing on sustaining innovation with consistent product improvement by adding unique features plus better customer services. Continuously tracking marketing trends, and monitoring customer feedback to stay ahead of the market competition. It is recommended to invest in Research & Development departments for exploring and developing new technologies and their applications like integration with home automation devices such as Alexa, biometric authentication, and even energy-saving technologies. Also, maintaining flexibility to incorporate market demands along with adjusting product services accordingly.

3. Technical Challenges:

Mechanism malfunctioning, software bugs, and problems in lock mechanism, can create a negative user experience which might cause the potential failure of the product. Investing in the proper robust testing for the hardware and software development would be helpful. In-depth testing of the unit, stress testing, and integration testing are essential to ensure that the system works properly or not. Using a 6-sigma methodology for continuous product improvement can be effective.

4. Customer Adoption:

Various Market Segments can adapt digital tap lock for varying rates depending on the perceived value, required functionality, and pricing. Designing Focused Market Strategies for different customer segments that explicitly focus on the features important to them (Security features required for commercial clients, easy usage for the elderly people)Introducing customized training along with the development of the process which addresses specific domains and runs the initial pilot programs and even focus groups to collect early feedback. Conducting a quarter market survey to refine customer outreach with adoption strategies.

5. Economic Components:

Economic fluctuations can impact the demand for products like digital locks which have cheaper options, and this may be a discretionary purchase for the customer. Continuous economic indicators monitoring can help in adjusting the pricing strategies, can offer flexible pricinging models, and can also offer discounts along with financial options. Conducting marketing campaigns helps in developing a sense of value for the product and helps convince customers of this need to shift to digital locks.

6. Supply Chain Disturbance:

Supply chain disruptions particularly for highly specialized components like microchips, actuators, and sensors can hamper production and restrict product availability. Making connections with diverse suppliers and securing numerous sources for highly specialized components to mitigate issues arising due to a single vendor. Always having a buffer stock for key components and having a contingency plan to deal with supply chain disruption. Develop

strong relations with all the suppliers and keep monitoring their capacity to meet the requirements.

7.Technological Competition:

The market trends in technology can introduce some new technology which can make the current model obsolete. Incompatible design or technological features could risk the market life of the product. Developing a modular design that can allow timely updates in the design. Also developing technology in such a way that online updates of the software can be timely sent to the device can help. Introducing new features and engaging with technological partners can help in bringing up the latest innovations and features to the product and can help the product to remain competitive in the market.

8. Environmental Effect:

The e-waste generation and the impact on the environment while manufacturing, disposing, and using the digital tap lock looks concerning. Also, the energy consumption in the entire manufacturing process needs to be analyzed properly. Adopting environment-friendly manufacturing processes, also using sustainable material alternatives and decreasing packaging waste could be helpful. Energy-efficiency designing and creating replaceable lock batteries could help in reducing e-waste. Promoting economic features can help gain the optimum performance of the device.

Safety Considerations and Mitigations for the Digital Tap Lock:

The strategies below are to ensure the product safety for the consumers using Digital Tap Lock:

1. Locking Mechanism Safety:

If the locking mechanism is malfunctioning, then this could lead to abrupt locking or unlocking of the device creating functional failure of the lock and security vulnerabilities. Using high-quality and robust components for manufacturing the locking system. If the failure occurs, then implementing a redundant mechanical process like manual operation or backup unlocking mechanism or feature could be helpful. Regularly testing the functioning of the locking mechanism can help in ensuring product performance under various conditions.

2. Data Protection and Privacy:

Digital Tap Lock being a smart device, can store user data which could be vulnerable to cyber-attacks or could have concerns regarding cyber-security and breaches. Building a robust encryption standard for storing the data and transmitting the data like AES-256, and TLS regulations. Frequently updating the Digital lock's firmware to address probable security threats. Providing customers with features like data anonymization or opt-out can ensure compliance with the laws of user privacy and security.

3. Emergency Unlocking System:

In case of power failure or system malfunction, the lock should provide an emergency unlocking mechanism for safety. Design the digital tap lock with an emergency key or manual override feature that works even when the electronic system fails. Ensure that the backup system is simple to use, secure, and accessible in emergencies.

4. User Knowledge and Feedback:

Users might struggle with how exactly to operate the product because of a lack of understanding of the user instructions. Initiate an interactive user-onboarding process to guide all the users in an active environment. Developing a robust support system for the customers. Starting a 24-hour contact line to address customer queries and issues.

5. Continuous Improvement of the Product:

Making sure that the product is safe and effective in the tech market according to the current

regulations. Develop a feedback mechanism to get customer feedback and a back-end team to actively work on the feedback. Creating an R&D team to constantly keep updating the device according to the emerging technology. Hiring safety experts to avoid the areas where potential hazards can take place.

6. Overheating of the device and Fire Hazards:

Overheating of electric components could potentially harm the entire product. Using good quality heat-resistant material in making the digital tap lock. Using thermal sensors can cut off the power in conditions where excess heating is happening. Testing the product in regular intervals of time.

8. Consideration of the feasibility and viability

A. Challenges in Production and Recommended Solutions:

1. **Precision in Manufacturing:**

    a. **Challenge:** Precision in manufacturing critical parts like locking mechanisms, areas to place biometric sensors, or digital interfaces for lasting performance is essential. **Solution:** Investing greatly in high-precision CNC machining, replacing conventional assembly lines with robotic assembly, using advanced modeling techniques. Implementing systems for advanced quality control that use automated techniques and testing, in-situ monitoring, or digitalized quality control systems during manufacturing is done to meet the standards.

2. **Complex Component Assembly Process:**

    a. **Challenge:** The complicated assembly of the digital tap lock including electronic parts, mechanical locking systems, digital displays, biometric devices can be challenging to assemble and prone to mistakes.
    b. **Solution:** Setting detailed assembly guidelines and giving strict instructions to the people on the assembly line regarding each step. Using robotics for repetitive assembly tasks to bring more accuracy. Developing modular assembly design for executing the assembly of the parts easily.

3. **Supply Chain Analysis and Management:**

    a. **Challenge:** Ensuring the stable, secure, and reliable supply chain for critical and highly specialized components such as biometric sensors, high precision and quality locks, circuit boards can face delays or even shortage of the components.
    b. Solution: Enhancing the number of suppliers for the critical components to keep the back up. Forming strategic partnership with the key component manufacturers. Always maintaining the excess inventory to maintain the supply chain flow. Keep a plan in place to procure from the alternative sources.

4. **Quality Assurance:**

    a. **Challenge:** Consistency in the quality of the product with critical electronic and mechanical components while simultaneously addressing the estimated defects.

b. **Solution:** Establishing an extremely rigorous quality control system in manufacturing. Use of highly accurate automated testing methods for electronic systems, stress tests of mechanical components and implementing failure analysis tests to avoid potential risks and failures in the performance.

5. **Cost-Effectiveness in Production:**

    a. **Challenge:** Managing production and balancing the requirement of advanced technology with high-end material and cost control.
    b. **Solution:** Constantly reviewing the production cost to optimize the overall cost consumption by identifying the areas of excess cost consumption. Making negotiations in bulk orders of the components, and implementation of the lean manufacturing to decrease or completely eliminate waste in the production.

6. **Training of employees and recruiting skilled labor:**

    a. **Challenge:** Assessing the skillset of the production team to ensure that the team handling manufacturing and assembly of the complex components has the required skills and qualifications to carry out the required work successfully.
    b. **Solution:** Creating a holistic training program for the employees to convey the standard assembly procedures, quality checks, and safety requirements. Providing facilities for employees to continuously learn and develop their skillset. Developing partnerships with academic institutions and offering programs for the employees to give them the opportunity to learn.

7. **Scaling up the Production:**

    a. **Challenge:** To scale up the production so that the rising demand for the product can be met without failing to meet the required quality and increase in the lead time.
    b. **Solution:** A proper plan to scale the production without affecting the quality and the lead time can be made. Manufacturing processes can be adjusted in such a way that they can handle the large volume of production. Developing modular production lines and even assigning flexible workforce to handle the increased demand. Continuous evaluation of the manufacturing processes and produced products for quality assurance.

8. **Reducing Environmental Impact:**

    a. **Challenge:** Decreasing the adverse impact of manufacturing the components for part production like batteries, plastic parts, and circuit boards.
    b. **Solution:** Implementing sustainable manufacturing processes along with the enhanced use of biodegradable material or material with lower environmental impact. Using energy efficient manufacturing processes and actively implementing waste segregation and reduction methods. Training the staff in energy efficient production and waste reduction practices. Assessing the End-of-life recycling alternative for the product.

9. **Compliance Standards:**

a. **Challenge:** Ensuring that the digital tap lock meets the international standards and regulations for safety (biometric data) and has electromagnetic compatibility.
b. **Solution:** Being informed about the recent ISO standards for digital locks like ISO 9001 and the allied certifications for electronic goods. Frequent audits of all the production processes can help in maintaining compliance. Collaborations with the regulatory bodies help in evolving the development of the digital lock consistently.

Digital Lock Cost Analysis:

The influence of the technology and features in the product can influence the pricing strategy as follows:

1. **Basic Accessibility:**

    a. **Features:** Including basic digital lock pad features with tap locking using PIN code can be included in the basic version.
    b. **Target Customers:** All the Budget-conscious customers who need basic lock fr the safety of their scooter.
    c. **Pricing:** The basic model will be the most price-efficient model with a great focus on affordability.
    d. **Pricing Strategy:** Price-sensitive consumers and the more focus will be on maintaining the affordability of the product.

2. **Moderately Premium:**

    a. **Features:** This product version would include some additional security features such as Bluetooth connect android/iOS app or face/fingerprint recognition.
    b. **Target Customer:** Residential areas, medium-sized offices, apartment complexes where slightly better security is required.
    c. **Pricing:** Moderately costly product with few advanced features and sophisticated design or AI integration.
    d. **Pricing Strategy:** Maintaining the affordability of the product and increasing the cost in moderation so that the above average consumers can afford it.

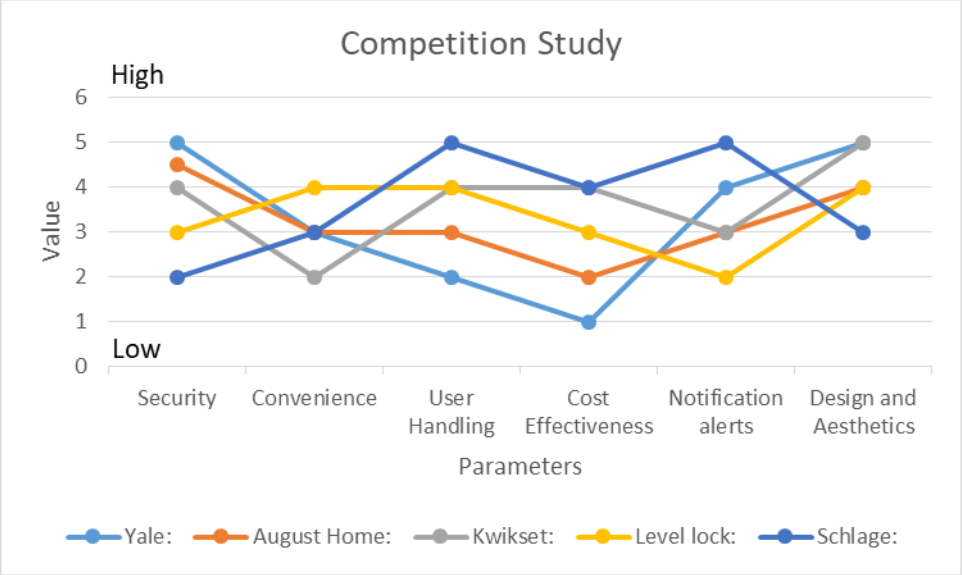
3. **Premium:**

    a. **Features:** This Version of the Digital tap lock should include advanced features like biometric access, remotely monitoring the scooter, multi-factor authentication through cloud services to provide the enhanced security option.
    b. **Target Customer:** Top-end residential complexes, company townships, commercial areas can have the targeted customers for this digital tap lock.
    c. **Pricing:** The Premium version will be at comparatively higher price as it will include sophisticated biometric authentication and high-end security features.
    d. **Pricing Strategy:** The cost will be allocated with the emphasis on increased and seamless user experience.

4. **Ultra Premium:**

a. **Features:** This top-end model will include cutting-edge technology such as AI based threat identification facilities, notification of unauthorized access request, smart phone integration, availability of battery back-up, and real-time monitoring.
b. **Target Customer:** Luxury housing societies, government bodies, banks and any other highly security sensitive areas.
c. **Pricing:** Thie Ultra-premium model would be highly costly model out of entire series as it contains the cutting-edge features and other smart systems.
d. **Pricing Strategy:** This is aimed to be the top end model in such a market where customers are willing to pay for the top end model to get all the convenience and comfort.

Competition Study Graph:



1. Security:
   - Yale: High - known to deliver high security
   - August Home: Moderate – Offers required security and delivers safety
   - Kwikset: High - known for providing tight security
   - Level lock: High – Famous for precise security solutions
   - Schlage: Moderate: Offers accurate and required security
2. Convenience:
   - Yale: Moderate – Allows user to unlock using smartphones
   - August Home: High – More compatible with smart home systems like Alexa
   - Kwikset: High – Ability to lock/unlock automatically as the user approaches or goes away from the lock
   - Level lock: Moderate – Easy installation and user handling process
   - Schlage: Moderate- It has intuitive control but slightly less user friendly
3. User handling:
   - Yale: High – Offers interactive user interface
   - August Home: High – Easy for user to operate
   - Kwikset: High- Offers multiple access methods using smartphones and ipad

- Level lock: Moderate – Hard to handle and complicated use
- Schlage: Moderate – Difficult to manage by multiple users like family members

4. Cost effectiveness:
   - Yale: Moderate – It has maintenance related cost involved
   - August Home: High – It has features like integration with multiple devices
   - Kwikset: High – These locks are known for their robustness and reliability
   - Level lock: Moderate – There is slightly greater cost associated with servicing etc.
   - Schlage: High – Offers range of locks and competitive prices making it affordable
5. Notifications/ Alerts
   - Yale: Moderate – Limited customizable settings
   - August Home: High – It provides real-time notifications and alerts
   - Kwikset: High – Provides necessary notifications with low battery alerts as well
   - Level lock: High – Allows customizable notifications enabling user to choose the notifications they want to receive
   - Schlage: Moderate- Limited settings for managing notifications
6. Design and Aesthetics:
   - Yale: High – It has clean lines and unobtrusive appearance
   - August Home: High – It has sleek look and various designs available
   - Kwikset: High – Is available in multiple colors and shapes
   - Level lock: High – Lock offers various finishes and is sleek in look and visually appealing
   - Schlage: Moderate – Lock is manufactured with user centric approach and easy to handle

9. Design the Product Using the Principles of Circular-Design

Circular Design for Digital Lock:

Material Choice

In order to align the material used in digital lock to circular design principles, choosing the right sustainable materials plays a crucial role. The choice of materials should be based on durability, longevity and after considering the environmental impact.

1. **Metals:**

   a. **Recycled:** Using durable and corrosion-resistant material which can be recycled without choosing their properties is essential. Using such recycled materials is environmentally friendly and sustainable practice.
   b. **Benefits:** Using recycled material instead of virgin material helps to maintain the virgin material inventory and save the cost. Precision manufacturing of these materials is comparatively efficient helping them to provide manufacturing efficiency.

2. **Electronics:**

    a. **LED / OLED Screens:** The digital locks often include display screens as a user interface. Modular LED or even OLED screens are highly energy efficient producing great performance and quality with a good lifespan.
    b. **Energy Efficiency:** These display screens consume much less power and hence help in saving the device battery and contributing ot the overall sustainability of the divice.

3. **Plastic Parts:**

    a. Using bioplastic for the non-load bearing parts such as lock housing can help in enhancing the biodegradability of the tap lock.

Packaging Design

Minimalistic and Reusable Packaging Practices can help in redunc the packaging waste generation by significant amount:

a. **Biodegradable Materials:** Using recycled cardboard for the packaging component can help reduce the environmental harm by reducing the waste generated.
b. **Multi-purpose Packaging:** Designing packaging in such a way that it can act as a storage space for the lock even after unpacking. This could help in reusing the packaging.

Repair and Recycle

For enhancing the longevity along with the repairability fo the entire aasembly of the digital tap lock, using modular components cols play a crucial role.

a. **Modular Design: Purposefully** avoiding complex and excessively specialized components in the product. Opting for the standard parts available such as screws, circuits and displays as they are easily available and accessible in the market.
b. **Modular Components:** Designing lock with easy modular components to make the repair process easy instead of discarding the complete product.

End-of-Life Program

The **End-of-Life management program** is extremely crucial for circular design and it make sure that the product is mostly recycled instead of going into the landfills.

1. **Product Return and Recycling:**

   Creating an EOL help to facilitate the return plus recycling of the old locks. Providing Mail-in services for customers to return the old locks, specifying the exact drop-off locations, having in-store return facilities can help to ease and channelize this process perfectly.

2. **Recycling plus Repurposing Components:**

   Refurbishing electronics, recycling the bio-degradable materials and reusing the metal components in future locks can help reduce severe environmental impact.

3. **End-of-Life Digital Integration:**

   Developing website where easy return and tracking of End Of Life by the customer will be extremely easy. This would enhance customer participation in proactively returning the product.

4. **Customer Incentives:**

   Keeping rewards like a point system or providing gift cards for the customers who participate in the end-of-life program can encourage their participation.

5. **Feedback and Improvement:**

   Actively collecting customer feedback by providing them with online feedback forms and acting upon the feedback received can be helpful to further expand the EOL program.