Final Summary Report

SLIDECK

A Product by **Commuter Bikes Cooperative**

Mechanical Engineering 110

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Abstract

Our team at Commuter Bikes Cooperative sought to design and prototype a foldable bicycle pedal optimal for the urban commuter. We conducted customer interviews and concluded that the top five customer needs were safety, modularity, size, performance, and grip. Based on these customer needs, we ideated five concepts and utilized a Pugh Chart to down select three for rapid prototyping. Of these three concepts, our first concept could fold with a kick of the rider's heel like "origami." Our second concept has a stock pull-push pin on the top of the pedal that unlocks the folding mechanism. Finally, our third design has a latch within a slot and groove that unlocks the folding mechanism. Based on the difficulties of prototyping the first two concepts and the limitations of 3D printing, our group settled on iterating only the third concept, adding magnets, a neoprene covering, grip tape, and a TPU cage. We created two final prototypes: (1) a "works like" prototype that incorporates a bicycle bearing to test the functionality of the pedal, and (2) a "looks like" prototype with external attachments and an updated body that enhances the aesthetic appeal. Our team's next steps include updating CAD with DFM and DFA in mind, as well as collaborating with our manufacturing partners to prepare for mass production and expanding our product portfolio.

Market and Customer Research

To begin the product development process, our team set out by identifying a problem to solve. The team individually generated five potential product concepts to pursue that were in the scope of our time frame and skill set. After deliberation, the team ideated a foldable bicycle pedal. There are a handful of team members who commute to school by bicycle and unanimously complained about the problem of colliding with one's bicycle pedal on a daily commute. Therefore, the team decided to pursue the idea of making a foldable bicycle pedal that is optimized for the urban cyclist.

After making our selection, we completed market research to explore the potential opportunity space. The United States Census published a survey[1] in 2014 that shows how over the last decade, the number of individuals choosing a bike as their primary mode of transportation to work or school has steadily increased. With roughly 786,000 yearly bicycle commuters paying around $20 for pedals, the current market size is $16,000,000. Given the trend of cyclists over the last decade, there is promise for this industry to continue to grow. This census also allowed us to pinpoint our target market: young commuters who live in urban environments, especially men. While a significant amount of research and investment goes towards developing professional bicycle pedals, the lack of evolution in commuter pedal design alongside a growing market presented us with the optimal opportunity for success.

It is important to note that folding pedals do currently exist on the market. However, the Sunlite Folding Pedals 9/16” and MKS FD-7 Folding Pedals 9/16” sport customer reviews that claim the pedals are too stiff, too heavy, or too rickety. As shown by Figure 1, we developed a perceptual map of the market based on the comfort and modularity of competitor pedals. We plotted other pedals based on customer reviews, as well as our own experience with the products. We recognized opportunity existed for a solution that maximizes the user’s experience of comfort and modularity. As a result, we developed a competitive strategy around differentiating our pedal on the basis of these two features.

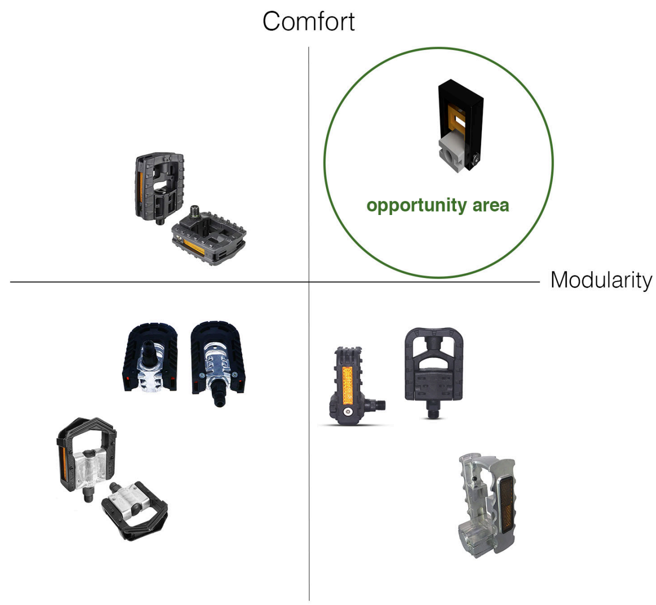

Figure 1 : Perceptual Map of Competitors and Opportunity Space

Beyond market research, we conducted over 30 user interviews in order to gain insight into our customer base. We reviewed all of the interviews as a team in order to tailor our design to accommodate and meet customer needs. After categorizing and clustering feedback, we found our top five needs to be: safety, modularity, size, performance, and grip. Specifically, the most common need statements indicated that individuals want a pedal that is sized to their foot, provides sufficient grip for everyday shoes, supports their weight in and out of the saddle, and is lightweight and modular enough for easy carrying and storage. We were able to visualize the customer experience using an empathy map shown by Figure 2. By ranking and clustering need statements, we were able to get a sense of what a customer experiences when purchasing and using a pedal on the market today. The top customer needs, along with the differentiating factor of comfort, became the driving motivation for the design specifications in our product spec.

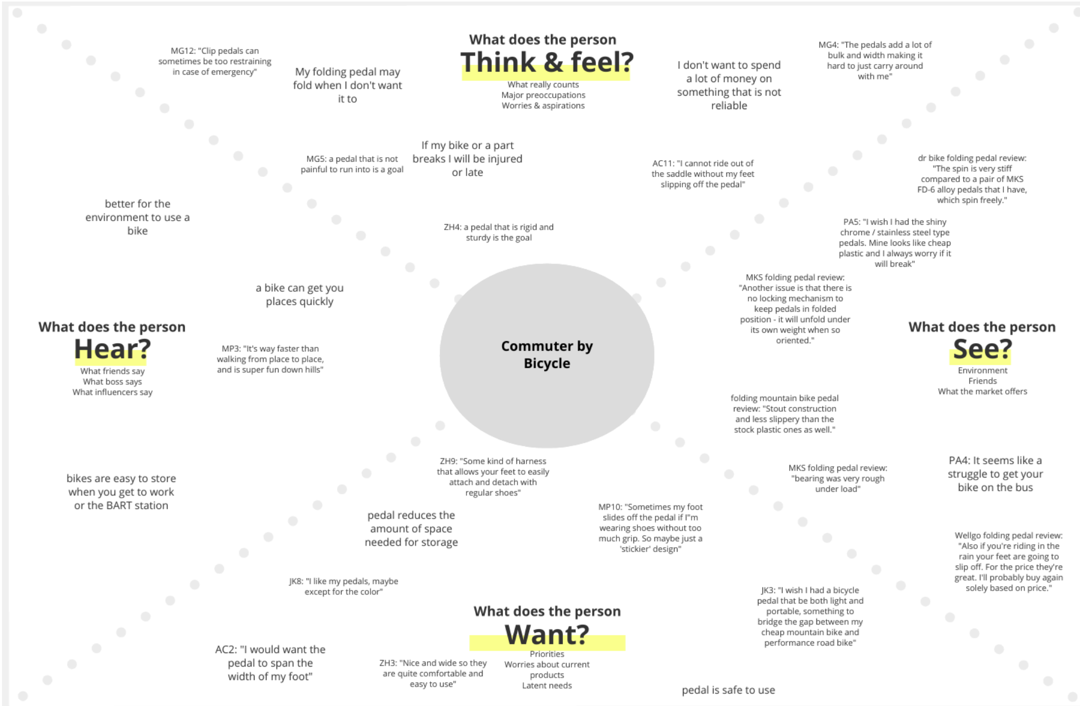

Figure 2 : Empathy map of customer needs

From this point, we began to develop a product spec as a team. This spec defines the developed solution with our customer in mind. This process began with defining user personas. There are two main personas we designed a solution for: the college student looking to improve his/her overall riding experience by maximizing safety, comfort, and performance, and the daily working commuter who prioritizes reliability, efficiency, and modularity while on the go. As a result, the product specifications prioritized a secure locking mechanism to achieve foldability. The final prototype was specified to be a 3D printed body with an off the shelf bearing, while our final product will be injection molded nylon with a metal spindle and high quality bearings.

The research and project planning did not come to an end when we began concepting. After refining our final prototype design, the team conducted a patent literature search to ensure the intellectual integrity of our product. We categorized and ranked over 15 existing patents to both learn from and protect the work of other designers. The team identified where our product championed others, but also were exposed to unique or more efficient ways to solve various problems we had. This literature search offered a lot of perspective about alternative design routes we had not yet considered.

Design Ideation

After the team chose to move forward with developing a folding bicycle pedal and defined the user needs, each member ideated 10 different concepts. The team then came together and reviewed all 60 concepts, discussing different aspects of the designs and brainstorming about how to combine favored ideas. At the end of the session, we developed five core concepts that combined the best aspects out of the 60 concepts generated.

<table>
<tr><th>Concept 1</th><th>Concept 2</th><th>Concept 3</th><th>Concept 4</th><th>Concept 5</th></tr>
<tr><td rowspan="3">MG: Adjustable in size</td><td>MG: Folds upwards 90° & has soft edges</td><td>AC: Folds 180°</td><td rowspan="3">JK: Origami style pedal</td><td>AC: compression driven lock</td></tr>
<tr><td>ZH: Detachable Cage</td><td rowspan="2">PA: Pinch and fold locking mechanism & soft grip</td><td rowspan="2">AC: Body style modeled after performance pedal</td></tr>
<tr><td>MP: Folds with

hinge</td></tr>
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Table 1: Top Five Concepts

The team took the five concepts and selected three to pursue for rapid prototyping. The three concepts selected for rapid prototyping were concepts 2, 4, and 5. However, concepts 2 and 3 were again reconceptualized to create a hybrid concept that could fold 180°, has a detachable cage, soft edges, grip tape, and folds with a hinge. The team took these three finalized concepts to the next development phase: rapid prototyping.

Rapid Prototyping

After narrowing down to the three design concepts, we began the rapid prototyping stage of our development process. We decided that additive manufacturing was the best available prototyping method that suited our needs. We first printed concept 5, the folding pedal with spring loaded pull/pop pin, with the Series 1 Type A 3D Printer. From this concept's initial prints, we learned that the Type A 3D Printers at Jacobs Hall did not meet the needed design tolerances. While the pedal body and spindle fit as designed, the support structure within the pin hole of the pedal body interfered with the pin. Furthermore, we experienced multiple print failures with the Type A 3D Printer. After this design iteration, we decided to solely print with Ultimaker 3D Printers due to the higher print quality and tighter tolerances. We also learned that our pedal design was both wider and thicker than typical bicycle pedals on the market. After fully visualizing the physical prototype, we recognized the design flaw, adjusting the pedal's thickness and overall surface area.

After modeling concept 4, the origami inspired pedal, in SolidWorks, we discovered that the design required many hardware components because of the 8 joints, posing a threat to the structural integrity of the part. Despite our initial reservations, we took the initiative to print the concept design using Jacob's Ultimaker 3D Printers. Half of the design components came out well, but some pieces did not fall under the tolerances necessary to bring the design to fruition. After this design iteration, we decided to set aside concept 4 due to the complexity of the design and necessity to replace 3D printed components with machined parts.

A track and groove mechanism inspired the locking component of concept 2, where a tab locks the pedal in either an upright or horizontal position. In order for the tab to remain in the locked position, we needed a constant force pushing the tab. Thus, we researched and prototyped with various springs and repelling magnets. Unlike springs, magnets do not wear from overuse; therefore, the magnetic design performed more smoothly compared to the spring. In our first iteration of this design, the pedal rotates about a cylindrical joint, but this joint design required the pedal to be printed as two separate pieces in order to assemble the prototype. We decided to replace this cylindrical joint with shoulder bolts that attach the pedal body to the spindle and allows for a smooth rotation. We also learned that the contact area between the sliding tab and groove generated too much friction, making it difficult to slide the tab in and out of the locked position. After prototyping each concept, we decided that redefined concept 2 satisfied our customer needs better than the other contenders, so we chose this concept as our final solution.

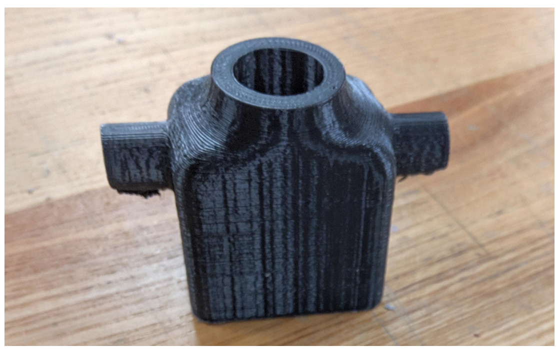

Figure 3: Failed FDM PLA 3D print of pedal spindle

Final Solution

The final solution addresses the outlined five user needs and achieves the function of a folding pedal with a creative and aesthetic design. There are three overarching design goals that the team set to accomplish with the final solution. The design goals are broken down into the folding mechanism, the user experience, and modularity.

The design goal of the folding mechanism is to design a reliable joint that folds from a horizontal position for biking to a vertical position for storage, locking in each orientation. The locking mechanism is based on a track and groove mechanism, where a pull tab slides out of its locked position in the spindle, allowing the pedal to rotate between the folded and riding positions. To ensure that the locking mechanism does not slip out of place, a 6lb pull magnet is placed on the back of the locking mechanism pull tab and an opposing 8lb push magnet is placed inside the pedal body. The magnets repel one another and the resultant force works to keep the pull tab in place. Additionally, the spindle has two sets of slots that the locking mechanism slides into in the riding and locked position. This ensures that the rider is engaging with the pedal only at the 90° position.

The design goal for the user experience is to improve safety through the utilization of grip tape, neoprene cushioning, reflective tape, and a removable cage. Unlike the competitor folding bicycle pedals on the market that utilize extruded edges to provide grip, this folding pedal utilizes grip tape to provide traction for the rider but prevent injury in the event of contact. The pedal is also lined with neoprene to soften the edges of the pedal and add cushion between the rider and the plastic pedal body in the event of contact.

The design goal for modularity is to design for assembly by building the pedal from three separate modular pieces: pedal body, spindle, and locking mechanism. All three parts are designed for injection molding manufacturing methods and optimize assembly by removing the need for small hardware. The only hardware the pedal requires are the bearing, the two shoulder bolts to secure the bearing, and two magnets for the locking mechanism.

The team created two iterations of the final design. The first is the “works like” prototype that incorporates a bicycle bearing in order to test the functionality of the pedal, and the second is a “looks like” prototype that has an updated body style to enhance the aesthetic appeal of the pedal.

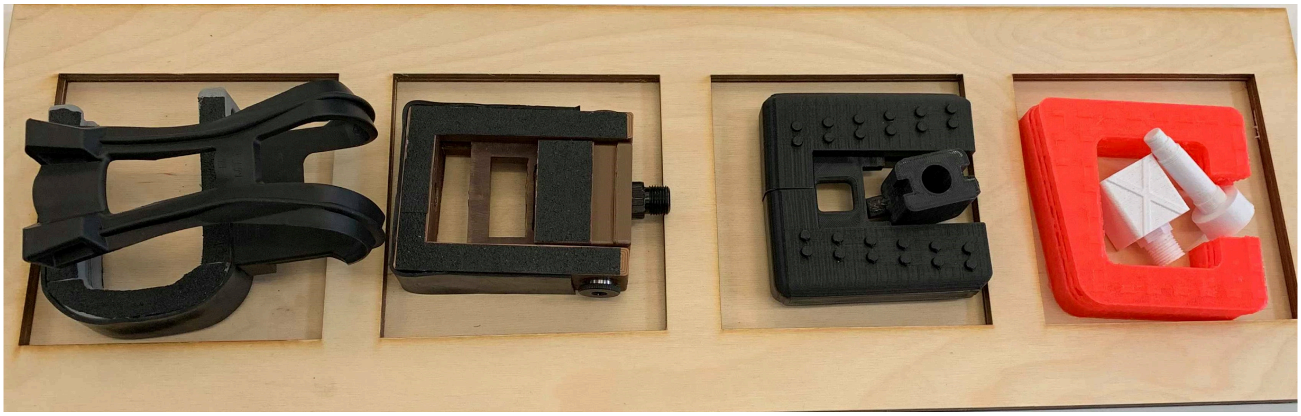

Figure 4 : Succession of various prototypes (from right to left)

Lessons Learned

The team learned many lessons throughout the design process of Slideck. During the design ideation process, we learned to identify an opportunity area and understand consumer needs. The conceptualization process taught the team how to constructively iterate through design ideas. Finally, during the realization process, the team learned how to test the identified success criteria. The team decided to conduct early prototyping and frequent iterations because of the lecture on building a marshmallow tower out of spaghetti. This lesson taught us, in a concrete way, how frequent and early prototyping iterations makes the best final product. The team utilized this learning by getting training on Jacobs Hall devices early on, iterating on SolidWorks concepts during every team meeting, and constantly testing the product. Nonetheless, the lesson of time still managed to be imperative. As the prototyping spaces became overcrowded, the team was halted on prototyping waiting for the parts to make it through the 3D printing que in the makerspaces.

Next Steps

After various prototypes and extensive feedback from the design showcase, Commuter Bikes Cooperative feels confident that our Slideck bicycle pedal is capable of meeting the needs of bicycle commuters. However, before taking the product to market, we need to conduct thorough consumer viability as well as economic analysis to validate this product before we invest in mass manufacturing and brand development. If and when we are able to further validate Slideck, we intend to refine the fidelity of the product by further improving on the CAD design with DFM (Designing for Manufacturability) as well as DFA (Designing for Assembly) in mind.

Our plans include close collaboration with a manufacturing partner to understand what the next steps are before mass production. As planned, our sales model will focus on targeting local and online markets as we capitalize on the increasing bike ridership in the American, as well as global market. Once we generate enough revenue, we also have plans to expand our product portfolio whilst sticking to our brand identity that focuses on maximizing the safety and comfort of commuter biking.

Citations

[1] United States, Congress, Census Bureau, and Brian McKenzie. "Modes Less Traveled—Bicycling and Walking to Work in the United States: 2008–2012." *Modes Less Traveled—Bicycling and Walking to Work in the United States: 2008–2012*, US Census Bureau, 2014, pp. 1–18.