rack.it

bike parking for the 21st century

March 18, 2015
Prof. Goldsmith & Prof. Le
The Art and Science of Engineering Design
Stephanie Chen, Caroline Debs, Alex Lee, Cindy Wang
Breakdown of Responsibilities (by document section)

**Stephanie Chen** - Abstract, Design Constraints, Initial Design Sketches and Analysis, Materials and Cost Estimate

**Caroline Debs** - Executive Summary, Overview, Problem Statement, Implementation Overview, User Testing, Production Schedule, Future of rack.it

**Alex Lee (Editor)** - Problem Statement, Models of Final Design


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I. Abstract (Stephanie)

The bike parking process is essential to the daily lives of thousands of students on Stanford’s campus, but the hassles of cumbersome U-locks, easily lost keys, and inconsistent rack designs make parking an overall negative, time-consuming experience. Our bike rack design features a single, minimalist support post with an LED availability indicator; bikes are secured with a high-strength chain and locked through SUID scan. Emphasizing flexibility, simplicity, and efficiency, our design aims to make the bike parking experience as smooth and satisfyingly unobtrusive as possible.

II. Executive Summary (Caroline)

A majority of students opt to bike Stanford’s sprawling campus. The current options for bike parking on campus, however, are inadequate. The process of transporting a heavy U-lock (Figure 2.1) while biking and the act of struggling with a key and U-lock to secure a bike are inefficient. rack.it aims to simplify the bike parking experience. With its novel design, users will no longer have to purchase or deal with U-locks. Moreover, they will no longer have to worry about quickly securing their bikes before classes or important meetings. To operate the rack.it, users will simply scan their SUID, which they already use for dining hall and dormitory access. With a single scan of the SUID, a sturdy cable will be released to loop through the bike frame. The end of this cable will then be fed into a slot in the rack.it, creating a complete loop and securing users’ bikes until they return. This gives users the freedom to secure both wheels and the frame, which is more security than a single U-lock can provide.

![Figure 2.1: The traditional U-lock with accompanying keys.](http://bikereviews.com/wp-content/uploads/2009/12/trek-streetwise-u-lock1.jpg)
III. Introduction

A. Overview (Caroline)

Stanford's campus—which consists of 8,180 acres—is expansive. The average distance from students' dorms to their classrooms is half a mile. Therefore, most students at Stanford choose to bike to class to save time and energy. They depend on university-provided bike parking to keep their bikes secure while attending class. Despite the efforts of the university to keep bikes secure, around 350 bikes are stolen each year. This rack.it aims to make bike theft a non-issue for busy, stressed-out students. No longer will students have to struggle with securing a bike with a U-lock or finding a free parking slot. Locking a bike will now be as easy as scanning an SUID.

B. Problem Statement (Caroline + Alex)

The bike parking provided by Stanford University should aim to provide students and faculty with the most time- and space-efficient way of storing their bikes. The process of parking a bike on campus should be fast and intuitive, using as few separate parts as possible. Students should be able to rely on ample and secure parking spots, available in close proximity to their desired destinations. Furthermore, bike parking should add to the aesthetics and functionality of the campus. However, bike parking at Stanford is currently tedious and unreliable. During peak hours of activity (i.e. around 11 AM, when many students have class), it is often impossible to find bike parking close to one’s classroom. Many students go to class significantly earlier just to secure a parking spot or resort to simply locking their bike wheels to their frames. Searching for a free parking spot also creates traffic jams. In addition, Stanford requires students to purchase their own bike locks, which cost around $35 (Figure 3.1). With 1,677 new freshmen arriving on campus each year, students pay around $60,000 for bike locks (~$35/lock) a year. Finding and fiddling with one’s lock to loop it around a parking station is also inefficient (Figure 3.1). The design of bike parking stations are also inconsistent and vary throughout campus (Figures 3.1, 3.2, 3.3). Some locations offer stations that secure only the front tire, making bikes with quick-release tires to be more susceptible to theft (Figures 3.2, 3.3). Furthermore, bike parking lots are eyesores because of the vast dirt lots studded with rusting black or metallic parking stations (Figure 3.2). In short, the current bike parking situation is inefficient, convoluted and unreliable.

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3 http://transportation.stanford.edu/alt_transportation/BikingAtStanford.shtml
Figure 3.1: A Stanford bike rack that only allows users to secure their bikes’ front tire.  

Figure 3.2: The dirt lot with bike parking in front of the Stanford Stadium. These bike stations only allow users to secure the front tires of their bicycles.  

Figure 3.3: A type of bike parking station available at Stanford.

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5 http://www.sacbike.org/wp-content/uploads/2013/03/Comb-rack.jpg
IV. Problem Analysis

A. Current Bike Rack Designs\(^8\) (Cindy)

<table>
<thead>
<tr>
<th>Design Name</th>
<th>Variant Names, Description</th>
<th>Image</th>
</tr>
</thead>
</table>
| U-rack        | - **Staple, Sheffield rack**  
- Simple rack used in urban areas, does not take large amounts of space away from pedestrians. | [Image](http://www.humantransport.org/bicycledriving/library/parking/parkingcommercial.htm) |
| Wave          | - **Serpentine**  
- Extension of the U-rack. Can hold more bikes, but only contacts the frame at one point rather than two, resulting in higher chance of bikes falling. | [Image](http://en.wikipedia.org/wiki/File:White_Winder_Bike_Rack.png) |
| Bollard style | - **Post and ring**  
- Short vertical posts with one or two arms to which bikes can be secured. | [Image](http://en.wikipedia.org/wiki/File:Bike_path_on_College_in_Toronto.jpg) |
| Grid style    | - Consists of vertical bars that connect larger upper and lower metal tubing. Does not allow both the wheel and frame of the bike to be locked, allowing for potential theft of the bicycle. | [Image](http://en.wikipedia.org/wiki/File:Mied%C5%BAno_stoja_k_na_rowery_30.04.11_p.jpg) |

\(^8\) [http://www.bikeparking.com/], [http://www.belson.com]
Innovative

- Designs incorporating both utility and appearance, usually resulting from minor changes to basic bike rack styles.
- Note: Photo to the right exhibits the "Stanford rack," designed at and currently widely in use at Stanford University.

Decorative

- Certain areas (commercial, governmental) may require racks with more unique aesthetics.

Double Deck

- Two-tier bike racks can be used to increase bicycle storage capacity in a fixed space. Some incorporate hydraulic pistons to lift the bike into the rack.

B. Supporting Materials (Cindy)

The literature we reviewed prior to embarking on our own model includes existing bike rack styles (summarized above), submissions from bike rack design awards and competitions, and official (municipal and professional associations) regulations regarding rack placement, composition, and form.

We first obtained cursory information from general sources (e.g. Wikipedia, bikeparking.com), then found more specific information in specialized articles, websites, and multimedia resources. We then incorporated our research with our personal observations and experiences into a communal brainstorming document.
1. Case studies from New York CityRack Design Competition

Selected passages from the New York CityRack website describe the need for modernized, efficient, and elegant bike rack design:

“The purpose of the competition is to develop functional, well-designed sidewalk racks and to generate new concepts for bicycle parking inside commercial and residential buildings...a study conducted by the Department of City Planning found that lack of access to secure bike parking was the primary reason cyclists did not ride to work.” (emphasis added)

Because of this emphasis on function and security, we decided to look to some of the competition guidelines to guide our own design process:

- “Designs shall avoid corrosion produced by metal-to-metal contact, including contact between the fixture and a standard bicycle.”
- “There must be a minimum two-point connection between the bicycle and the rack. That is, the design must allow for the bicycle frame as well as at least one wheel to be secured to the rack.”
- “The bicycle should not have to be lifted off the ground more than 6 inches to access and be secured to the rack.”

The winning design (Figure 4.1) of the sidewalk rack portion of the competition was a variation of the bollard style rack consisting of a single large metal hoop with a bar across the diameter. This design is secure because it allows many points of contact with the bike and is also aesthetically pleasing.

![Figure 4.1: The winning design by Ian Mahaffy and Maarten De Greeve.](https://nycityracks.wordpress.com/design-guidelines/)

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9 https://nycityracks.wordpress.com/design-guidelines/
2. Official bike parking regulations

The Washington, D.C. Department of Transportation\textsuperscript{10} sets strict regulations on acceptable types of bike racks (Figure 4.2).

\textbf{UNACCEPTABLE DESIGNS}

\begin{itemize}
  \item This type of rack can bend the wheel.
  \item This type of rack does not support the bicycle frame in at least 2 places.
\end{itemize}

\textbf{RACK ELEMENTS}

The rack must:
\begin{itemize}
  \item Support the bicycle frame in at least 2 places, allowing the frame and wheel to be locked using a U-lock or cable lock.
  \item Prevent the wheel of the bicycle from tipping over.
  \item Not damage the bicycle.
  \item Be durable and securely anchored.
  \item Allow front-in or back-in parking.
\end{itemize}

\textbf{Figure 4.2:} An excerpt from the DC District Department of Transportation Bicycle Facility Design Guide.

Other documents referenced include bike parking design and management guidelines from Toronto\textsuperscript{11}, San Francisco\textsuperscript{12}, and Minneapolis\textsuperscript{13}. Each of these contain extensive measurements and requirements regarding materials, anchoring, placement, spacing, capacity, and security of public bike storage resources. We used this literature to place benchmarks for safety and usability in our final design.

\textsuperscript{10} http://ddot.dc.gov/sites/default/files/dc/sites/ddot/publication/attachments/bicycle_rack_design_and_placement_guidelines.pdf
\textsuperscript{11} http://atfiles.org/files/pdf/Torontobikeparkguide.pdf
\textsuperscript{12} http://www.sfmta.com/sites/default/files/pdfs/Bicycle_Parking_Guidelines.pdf
\textsuperscript{13} http://www.ci.minneapolis.mn.us/www/groups/public/@publicworks/documents/webcontent/convert_283358.pdf
3. Partial brainstorming document (all)

Problems:
- Inconsistent design
- Lots are made of dirt
- Wire racks are bent to the side
- Disconnected parts
  - Need to carry a lock around
  - Need to keep track of where key is
- Bike racks only have one purpose
  - Aesthetics (lack thereof)
  - Don't protect against the rain
- Bike racks are always made of metal
- Time
  - Bike locking process takes time
  - Too long to get bike out
  - (Locks) rust easily
  - Very physical process
  - Not enough bike racks
- Placement/Distribution
  - No easy flow of traffic (can't go through a rack)
  - None by Engineering Quad
  - Don't easily know which ones are free
  - Limited to where racks are placed
  - Traffic jams
  - Have to worry about not getting a spot
  - Take up a lot of space

Assumptions:
- Have to made of metal
- Attached to metal
- One purpose
- Need to have a separate lock
- Can't move
- Bike racks are free-for-all
- They have to be in rows
- Flat in front of the ground
- Have to be outside

Feelings about Bike Parking:
- Ugly
- Inefficient
- Tedious
- Low-tech
- Dirty
- Uniform
- Rushed
- Bland
- Permanent

IDEAS:
- Vertically staggered bikes (with ramps)
- Movable bike racks (on lampposts or st)
- Something to tell you where free parking is
- Holes (ports/stations) in the ground
  * Can't see from far away
  * Have to bend down
- Image: sunflower bike rack
- Rack that integrates lock

C. Design Constraints (Stephanie)

Before deciding upon objectives to pursue in our bike rack design, we established the following constraints in order to ensure that our design improved upon existing models without sacrificing their effectiveness, security, and efficiency.

Security: First and foremost, our design should reliably secure users' bikes at least as well as current designs paired with a U-lock. Any design must fulfill the most basic purpose of a bike rack, which is to anchor a bike to an immovable surface while allowing the owner to secure and remove it. Locking components should be resistant to bolt cutters, loosening, and lockpicking; on the other hand, bike owners should always be able to unlock their bikes.
Identifiability: Our rack design must be easily identifiable as a place to secure one’s bike. While aestheticism is desirable, overly decorative designs like that in Figure 4.3 below are difficult to recognize as places to secure bikes—especially when first introduced onto campus—and reduce overall time efficiency for students.

![Figure 4.3: A highly decorative but not so easily identifiable bike rack.](image)

Durability: Our design must also be at least as durable and long-lasting as existing designs, which typically last many years. It must resist weather conditions ranging from extreme heat (>110°F) to heavy wind to prolonged rain; for example, materials should be waterproof without rusting, and moving or electrical components should last without need for regular maintenance. The rack should also resist mechanical forces and daily wear from users parking and removing their bikes.

Flexibility: Our design should accommodate all the shapes and sizes of bikes typically used on Stanford’s campus, accounting for differences in wheel diameter and thickness (e.g. cruiser bike vs. road bike), frame design (e.g. step-through vs. triangle), and handlebar width. It should also accommodate bikes with fenders as well as attached front and side baskets. While several other means of transportation (adult-sized tricycle, scooter, etc.) are sometimes used on campus, their owners are in a small minority that we do not include in our user base.

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V. Design Thinking

A. Objective Tree (all)

![Objective Tree Diagram]

B. Morphological Chart (all)

<table>
<thead>
<tr>
<th>Functions</th>
<th>Possible Means</th>
</tr>
</thead>
<tbody>
<tr>
<td>Notifies that rack is available</td>
<td>Lights, Sounds, Flags, Smartphone, Remote, Temporary combination locks</td>
</tr>
<tr>
<td>Protects unique users from theft</td>
<td>U-locks (from rider), Locks (built-in), Cable/chain locks, Phone authentication, SUID scan, Obvious closed loops</td>
</tr>
<tr>
<td>Identify as bike rack</td>
<td>Looks like a traditional bike rack, &quot;Bike Parking&quot; signage, Rack shaped like a bike, Plays bike bell sound, Obvious closed loops</td>
</tr>
<tr>
<td>Accommodate different sizes of bikes</td>
<td>Vertically staggered, Variable spacing (movable rack spaces), Accommodates longboards as well, Hinged/movable rack parts</td>
</tr>
<tr>
<td>Contribute to other campus functions</td>
<td>Colorful (artistic), Integrated with nature/green spaces, Ads for campus events, Data collection for campus surveys, Benches/chairs, Solar panels/wind turbines</td>
</tr>
<tr>
<td>Resist forces</td>
<td>Inflexible (metal, durable plastics), Resistant to rust, Put structures underground</td>
</tr>
<tr>
<td>Increase user accessibility to bikes</td>
<td>Leave space for walkways between bike parking aisles, Bike parking spot flashes when your SUID is close, Customize bike racks to student traffic at each location, Lazy Susan</td>
</tr>
</tbody>
</table>
C. Initial Design Sketches and Analysis (Stephanie)

1. Stage 1 Gallery Sketches

<table>
<thead>
<tr>
<th>Sketches</th>
<th>Description</th>
<th>Analysis</th>
</tr>
</thead>
</table>
| Caroline | ● SUID scanner or touchpad to unlock  
            ● Horizontal bar extends and retracts to secure bike frame without need for user handling | ● SUID scanner idea allows quick and easy locking  
            ● Fewer complex parts on user side  
            ● Bar height would need to vary with bike height  
            ● Telescoping bar may be less secure |
| Stephanie | ● Portable rack to be attached to fixtures like lampposts and railings  
            ● Modules can be attached and detached to lengthen or shorten | ● Portability allows for flexible rack distribution  
            ● Doesn’t address issue of U-lock complexity  
            ● Might interfere with traffic |
| Alex | ● Dual-purpose rack with pedestrian bench on one side  
            ● SUID scanner to lock and unlock  
            ● Rubber clamps secure bike wheel to rack | ● Provides multifunctionality and campus aesthetics  
            ● SUID scanner is fast and effective  
            ● Locking only the wheel is less secure than locking the frame  
            ● Could result in overabundance of benches |
| Cindy | ● Post with flag that rises to indicate spot availability  
            ● Flag triggered by bike presence, most likely with weight | ● Availability indicator improves time efficiency in finding a spot  
            ● Movement of rising flag could be dangerous to users |
2. Stage 2 Consolidated Sketches

Design A (Alex):

This design was based on Caroline’s gallery sketch, featuring a telescoping horizontal locking bar that would pass through the frame of a user’s bike once triggered with SUID scan. It includes an adjustability function for the bar, allowing it to be shifted up and down in order to accommodate different bike sizes and frame shapes. In addition, this design adds an LED grid indicator to alert users to empty rack spaces.

Design B (Cindy):

This design incorporates the single-post model in Cindy’s gallery sketch but addresses the locking method by using a SUID scan to unlock. It includes a strong retractable steel cable with which to secure a user’s bike. Instead of alerting users to empty spaces with a physical flag, this design uses an LED display.
VI. Detailed Design

A. Final Design Choice and Selection Process (Cindy)

We went through several iterations of designs, each building upon and sometimes diverging greatly from the last. One of the most difficult tasks was weighing the tradeoffs between affordability, security, and scalability.

Because we established as a primary design objective that our project should eliminate the need for an external lock, our sketches all attempted to solve this problem, though they approached it quite differently in terms of materials used, space allocated, and locking mechanisms. The one feature for which we came to a consensus fairly quickly was that this could not be achieved without some method of verifying the identity of the user, and therefore, without a physically separate lock and key, the best solution was to implement a computerized system.

Given our experiences at Stanford and the wide usage of student ID cards at most universities (e.g. to enter buildings, swipe into dining halls, use learning resources, etc.), our second-stage mockups focused on designs involving an ID scan or swipe to access the rack. We also determined that in a non-university setting, a separate passcard or mobile application could easily take the place of an ID card.

From these discussions, we eliminated designs that did not prioritize the lockless feature or make use of ID card verification. Our two second-stage consolidated designs, Design A and Design B (see section V), were similar in concept but varied in implementation. We debated the various pros and cons of each approach at length to arrive at our final choice. For instance, Design A, composed of double posts with a telescoping metal rod, was time-efficient for the user because it involved spending little to no effort on securing the bike itself. However, the necessarily hollow rod brought up concerns about security, and the automated nature of a telescoping rod did not accommodate non-standard bike sizes and types well. Furthermore, the requirement of two mechanized units to secure a single bike was deemed expensive and space-inefficient. One the other hand, Design B, the single post with a retractable chain lock, had its main strengths in flexibility and visual aesthetic. The retractable lock, though slightly more cumbersome than an automatic rod, allowed users to secure bikes of variable sizes at several points of contact. Furthermore, the single post with a colored LED display to signal a free spot was space efficient and had a modern look. The primary concern of this design was the security of a chain lock, or rather, any flexibly shaped lock as opposed to a heavy-duty U-lock. However, we recognized that security would be a problem regardless
of whether we chose Design A or B and that it could be addressed in Design B by simply using a stronger material in the chain.

Our final rendered models largely represent Design B, which after taking into account all our design objectives and constraints, seemed to achieve the goals that we set out to accomplish at minimal expense of constraints like safety and efficiency. The figures below (Figure 6.1 - 6.6) show a SketchUp 3D model of Design B with minor optimizations to the wheel well and placement of the ID card reader. More technical sketches showing 2D views of the design, as well as the locking mechanism, are shown in Figures 6.7-6.10.

**B. Models of Final Design** (Alex)

![Figure 6.1: The final rack.it design.](image)

![Figure 6.2.a: 3:4 front view.](image)

![Figure 6.2: 3:4 back view.](image)
Figure 6.3: Side view.

Figure 6.4: Back view.

Figure 6.5: ID card reader.

Figure 6.6: Wheel well and chain.

Note: Due to Sketchup’s limited array of tools, a thick chain locking the bikes could not be rendered. Instead, a thin line is drawn representing the chain.

Figure 6.7: Front and back views (not to scale)
Figure 6.8: Top view (not to scale)

Figure 6.9: Side view (not to scale)

Figure 6.10: Simple diagram of locking mechanism (not to scale)
VII. Implementation

A. Materials and Cost Estimate (Cindy + Stephanie)

Bill of Materials

<table>
<thead>
<tr>
<th>Type</th>
<th>Materials</th>
<th>Cost per 36,000 units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct</td>
<td>High-strength polypropylene</td>
<td>$324,000 (~$1.00/lb)</td>
</tr>
<tr>
<td></td>
<td>Plastic coating for chains</td>
<td>$5,000 (~$0.20/lb)</td>
</tr>
<tr>
<td></td>
<td>Internal wiring, network structures</td>
<td>$180,000 (~$5.00/unit)</td>
</tr>
<tr>
<td>Intermediate</td>
<td>ID card reader</td>
<td>$1,440,000 (~$40.00/unit)</td>
</tr>
<tr>
<td></td>
<td>LED displays</td>
<td>$180,000 (~$5.00/unit)</td>
</tr>
<tr>
<td></td>
<td>Manganese-reinforced steel chain</td>
<td>$720,000 (~$20.00/unit)</td>
</tr>
<tr>
<td></td>
<td>Locking steel pieces for wheel/cable</td>
<td>$7,200 (~$0.20/lb)</td>
</tr>
</tbody>
</table>

Cost Estimates

Production (supplier costs)

<table>
<thead>
<tr>
<th>Cost</th>
<th>Estimate (per year for 36,000 units)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Employees: salary, insurance, payroll taxes, other benefits</td>
<td>$800,000 (50 manufacturing employees, outsourced)</td>
</tr>
<tr>
<td>Manufacturing: support costs, packaging, overhead</td>
<td>$1,200,000</td>
</tr>
<tr>
<td>Materials: raw supplies, resource transportation</td>
<td>$2,931,000</td>
</tr>
</tbody>
</table>

16 http://www.impreglon.us/front_content.php?idcat=131
17 http://www.homedepot.com/b/Electrical-Wire/N-5yc1vZbmTv
18 http://www.barodesinc.com/idtech/idtech-credit-card-readers.htm
20 http://bikesmarts.com/5-best-bike-locks-lightweight-secure-unbreakable/
21 http://www.metalprices.com/p/SteelScrapIronFreeChart
**Installation — covered by university (consumer costs):**

<table>
<thead>
<tr>
<th>Cost</th>
<th>Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Employees and associated costs</td>
<td>$22,000.00 (10 temporary employees)</td>
</tr>
<tr>
<td>Removal of existing bike racks</td>
<td>$7,000.00</td>
</tr>
<tr>
<td>Shipping</td>
<td>$5,000.00</td>
</tr>
<tr>
<td>Installation: landscape work, maintenance, SUID network implementation</td>
<td>$25,000.00 + ongoing maintenance</td>
</tr>
</tbody>
</table>

**Single-Unit Pricing**

Total Production Cost: $136.97  
List Price per Unit: $214.99 (57% profit margin)

**B. Overview of Implementation** (Caroline)

Coming up with a modern, original bike rack is just the beginning of our journey. Though we are confident in the abilities of the current model to securely and quickly allow users to protect their bikes from theft, overconfidence is not the key to successful implementation. However pleased we are with this current model, we recognize our satisfaction will not necessarily translate to the broader Stanford community. Therefore, we plan to conduct extensive user trials to reevaluate and modify our current model to be the best bike rack possible given our objectives for students and faculty. This means taking time to produce full-sized, functional prototypes to use in user-testing situations. We expect such assembly of prototypes to take around three months. We will then observe how users interact with the prototypes through the user testing methodology detailed in Section C: User Testing of Bike Rack Utility. Depending on user behavior, we will modify our design, build new updated prototypes and go through a second period of user testing. We will then use the data from our user testing to create new, updated prototypes. We will present these new prototypes to Stanford and ask for permission to implement them on campus. After these racks are implemented, we will note the successes and failures of our prototypes based on user behavior with the racks. We will notify Stanford of these successes and failures and ask for funding to improve upon our design and implement more rack.it bike racks around campus in the future. We expect this process up to the point of asking Stanford for funding to take approximately a year (Section D: Production Schedule).
C. User Testing of Bike Rack Utility (Caroline)

We expect to have two periods of user testing after completing our first prototype. We would like to run a few proof-of-concept tests in order to determine that our design works in the intended manner. For instance, we would want to make sure that students and faculty around campus can actually achieve the task of securing their bikes in a faster manner than they do with the traditional U-lock at various parking stations available across campus today. Furthermore, we want to analyze the failures and successes of the current prototype. Is the cable intuitive to pull out from the rack? Is the placement of the SUID scanner convenient? In what ways is the prototype breaking? We would want to have these test situations in real-world settings with the target audience: Stanford students and faculty. For instance, we could have our friends and professors use the bike rack in a central location which gives the bike rack visibility. This way the bike rack will become more integrated in student life and accepted by the Stanford community.

We will create a set of approximately 5 to 10 tasks for the participants to perform within a 10 minute period. Participants should be asked to perform the tasks with 4 prevalent types of bicycles -- a road bike, a mountain bike, a hybrid bike, a cruiser -- provided by the researchers. Researchers should remain neutral when interacting with participants and should reply to participant questions with open-ended responses such as “What do you think?” Researchers should take detailed notes and a videotape of the testing scenario to assess in depth later. The following sample tasks should be performed by the participants, without any guidance from the researcher:

1. Determine how to position a bike in relation to rack.it.
2. Determine how to swipe one’s SUID.
3. Determine how to extend the protruding cable.
4. Determine how to secure the bike with the cable.
5. Determine how to feed the cable back into the rack.it.
6. Determine when the process of securing one’s bike is complete.
7. Determine how to unlock one’s bike from the rack.it.
8. Determine how to terminate use of the rack.it station.

The usability of the device will be determined by the both performance and subjective measures such as:

1. Success rates (i.e. user knows how to use SUID scanner to gain access to the extendable cable)
2. Task times (i.e. the time user spends looping cable around bike)

23 http://www.usabilityfirst.com/usability-methods/usability-testing/
3. Error rates (i.e. user does not feed end of cable back into rack.it)
4. Satisfaction questionnaire ratings

The satisfaction questionnaire will consist of approximately 5 to 10 questions that the user will rate 1 to 10 (1 - do not agree, 10 - agree completely). The satisfaction questionnaire\(^{25}\) will have questions such as the following:

1. Overall, I am satisfied with the rack.it device.
2. The rack.it device is of very high quality.
3. The rack.it device meets my needs as a bike rack.
4. I am likely to use a rack.it product again in the future.
5. I am likely to recommend rack.it to a friend or colleague.

D. Production Schedule (Caroline)

NOTE: The starting date will be April 1\(^{st}\), 2015. Prototype 1 will represent our current prototype.

<table>
<thead>
<tr>
<th>April 2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sketching and design of prototype 1 (drawn sketches and 3D rendering)</td>
</tr>
<tr>
<td>An inventory of all parts and tools needed for production of the prototype 1 will be formulated.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>May 2015</th>
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</thead>
<tbody>
<tr>
<td>Purchase/gather all parts and tools from the inventory for prototype 1.</td>
</tr>
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<table>
<thead>
<tr>
<th>June 2015</th>
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</thead>
<tbody>
<tr>
<td>Assemble 10 functional prototypes of prototype 1.</td>
</tr>
<tr>
<td>Ask Stanford University for permission to implement a prototype in a frequently traversed area of campus.</td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th>July 2015</th>
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</thead>
<tbody>
<tr>
<td>First period of user-testing</td>
</tr>
<tr>
<td>User testing conducted as specified in Section C: User Testing of Bike Rack Utility. Videotape and take note of how students/faculty interacting with the prototypes. Analyze the footage and notes.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>August 2015</th>
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<tbody>
<tr>
<td>Take into account the results of first user-testing. Remake sketches and 3D renderings to take into account the results of user testing. Design prototype 2.</td>
</tr>
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<table>
<thead>
<tr>
<th><strong>September 2015</strong></th>
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</thead>
<tbody>
<tr>
<td>• Purchase/gather all parts and tools for the new design of prototype 2.</td>
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<thead>
<tr>
<th><strong>October 2015</strong></th>
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</thead>
<tbody>
<tr>
<td>• Second period of user-testing</td>
</tr>
<tr>
<td>○ User testing conducted as specified in Section C: User Testing of Bike Rack Utility. Videotape and take note of how students/faculty interacting with the prototypes of prototype 2. Analyze the footage and notes.</td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th><strong>November 2015</strong></th>
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</thead>
<tbody>
<tr>
<td>• Take into account the results of second user-testing. Remake sketches and 3D renderings to take into account the results of user testing to create the design of prototype 3.</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th><strong>December 2015</strong></th>
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</thead>
<tbody>
<tr>
<td>• Complete assembly of final products for prototype 3.</td>
</tr>
<tr>
<td>• Write up proposal about implementation of rack.it bike parking stations across campus to present to Stanford University in January.</td>
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</tbody>
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<table>
<thead>
<tr>
<th><strong>January 2016</strong></th>
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<tbody>
<tr>
<td>• Formally ask Stanford University for permission to implement prototypes on a greater scale around campus.</td>
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</table>

<table>
<thead>
<tr>
<th><strong>February 2016</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Implement racks around campus.</td>
</tr>
<tr>
<td>• Observe generally how users interact with racks, keeping in mind the tasks specified in Section C: User Testing of Bike Rack Utility.</td>
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</tbody>
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<thead>
<tr>
<th><strong>March 2016</strong></th>
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</thead>
<tbody>
<tr>
<td>• Report back to Stanford with successes/flaws of the rack.</td>
</tr>
<tr>
<td>• Ask Stanford University to fund the continuation and production of new iterations of rack.it devices.</td>
</tr>
</tbody>
</table>
VIII. The Future of rack.it (Caroline)

As excited as we are about our current prototype, we realize that we must keep updating the design to keep it in relevant in the ever-changing 21st century, especially at a school with such a prominent focus on technology. One idea we had regarding future additions to the rack was creating a companion mobile application that wirelessly syncs with the rack.it bicycle rack system. Such a mobile application could tell users where the most parking spots were free, as notifying users of rack availability was an initial goal of the rack.it team. Furthermore, we can better monetize rack.it racks by selling them to private enterprises on campus (i.e. Bytes Cafe, Starbucks, Coupa Cafe, etc.). Such companies would benefit immensely, as they would be able to offer their customers state-of-the-art bike parking. Grateful customers would come back more frequently. Furthermore, because rack.it integrates the SUID in its design, it would be able to gather information about its user. This could be beneficial to private campus enterprises, which could send users coupons and daily deals to incentivize spending. Overall, the future of rack.it is highly optimistic. There are many directions rack.it could take this design to better serve a growing, 21st-century consumer market of bikers. rack.it hopes to take advantage of these opportunities and create the bike rack of the future.