The Five Minute Solution Bicycle Lock

Design Team
Kevin Brousseau, Andrew Cannella, Jeffrey Haskell, Andrew Topar, Robert Townsend

Design Advisor
Rifat Sipahi

Abstract
The goal of this project is to design an easier solution for temporarily locking a bicycle than what is commercially available. Improvement can be made over current locks in the scenario where cyclists are only dismounting their bicycles for a short period of time, approximately five minutes or less, and they decide that engaging their lock is too much effort. The focus of this project is to design a bicycle lock that is effortless to engage and is also reliable enough to make the user confident that his or her bike will not be stolen while unwatched. The final design is a device that combines a kickstand with brake-type arms that clamp on the rear rim to prevent tire rotation. The lock is activated by the motion of putting down the kickstand, at which point brake pads clamp onto the rim of the tire. The lock is disengaged with a key tumbler built into the device. A 3D CAD assembly was created, detailing the different parts in the assembly, the materials selection, and how the components interact. From this a prototype has been created that demonstrates the functionality of the lock. Analysis and information regarding costs, manufacturability, adjustability, durability, and end-user experience has also been compiled.

For more information, please contact r.sipahi@neu.edu.
The Need for Project

Bicycles are commonly stolen when cyclists are dismounting for a short time when they feel it is too much hassle to properly use existing locking solutions. Reported bicycle thefts in Cambridge, MA have risen from 204 in 2006 to 356 in 2012. Many bicycle locking systems exist but most are too complicated or cumbersome to use quickly (Rep. 4.3). In a situation where the rider will only be away from the bike for a short time, they often consider their lock too much trouble to use, and leave the bicycle unsecured. A need exists for a quick and easy lock to address this five minute situation in an urban environment.

The Design Project Objectives and Requirements

Design Objectives

The main objective of this project is to create a bicycle lock which is fast and easy to use to ensure that the user will never be discouraged from locking their bike. It is also important that the lock disables the bike in such a way that it will be inconvenient for a thief to steal. The lock should also be easily portable (ideally fixed to the bike) to aid in its speed and ease of use. The weight of the device will also be an important factor. It is important that the lock is marketable, adoptable, tamper-resistant, and cost-effective (Rep. 3.1).

Design Requirements

It is important that the locking mechanism can be activated quickly, ideally in less than 5 seconds. Deactivation should also be as fast as possible, and thus should take no more than 10 seconds. The final design should weigh less than 5 pounds and should have a cost similar to existing locking products.

Design Concepts Considered

Five of the most viable designs were selected and developed from an expansive list of possible solutions. The group brainstormed over 25 ideas that satisfied the design objectives to various extents. The ideas were scored using a weighted design goal matrix. From this matrix, five designs were brought to life using 3D CAD to help visualize their strengths and weaknesses.
Rack and Kickstand Concepts

The rack concept and kickstand concepts are the two design concepts most similar to the recommended design. The rack mounts as a normal pannier rack would, above the rear tire, and includes a bar that swings down and locks to raise the rear tire from the ground to prevent riding. Optionally, the design could include a component that actuates through the tire’s spokes and a U-lock on the top of the rack for long-term security purposes. Similar to this design is the kickstand concept which serves the same purpose, preventing riding and serving as a kickstand, without the rack.

Both designs prevent riding the bicycle away, which is the main getaway means during theft (Rep. 4.2). The designs are portable and fast to activate. Both however, were deemed to be too prone to tampering and estimated to add too much weight to the bicycle to be successfully adopted. (Further information can be found in Rep. 5.2)

Other Concepts

A disk brake concept would consist of a box mounted to the rear axle which locks the rear tire when activated. It was determined that the forces the brake must resist were far too high for the mechanism to handle (Rep. 5.2). Two other ideas included a chain contained in the frame’s seat tube, which would require the bicyclist to find something grounded to attach the bike to and would not be easy enough to operate, and a U-lock attached directly to the bicycle’s frame, which would also require an object be available to ground the bike, and is not as flexible as a normal U-lock.

All of these preliminary concepts helped the group arrive at the final design. Their after-market nature, ease of activation, and portability remain in the final product. The concept of integrating the lock into an existing component of the bicycle is an insight from these initial concepts also used in the recommended design. (For further details see Rep. 5.2.)
Recommended Design Concept

The final concept is a bicycle frame-mounted kickstand that combines the best aspects of the preliminary designs. The device squeezes arms around the rear tire to prevent rotation without damaging the tire.

Design Description

The chosen concept is a kickstand and brake combination. It is a product of the group’s intensified focus on the “five-minute coffee break scenario.” The user activates the lock in the act of lowering the kickstand. When the kickstand is lowered, a shaft is rotated inside the case. There is a wire rope attached to the shaft which is pulled toward the front of the bike by this rotation. The pull of the rope in turn pulls on the arms. The arms pivot and clamp on the rim, preventing it from rotating. When the kickstand is lowered into the parked position, a ratchet and pawl mechanism prevents the kickstand from being raised until the pawl is disengaged via a key lock.

The lock is attached to the bike in the same area that a normal kickstand is attached. It clamps around the rear forks near the base of the seat post. It is bolted from the bottom in order to prevent tampering, as the bolt head is not accessible when the lock is assembled (Rep. 6).

Analytical Investigations

Components were designed to have as much strength as possible due to the large forces required to prevent wheel spinning, but the design was largely dictated by the limited space in the area where the lock is attached. Another point of focus with the analysis is designing a point of failure into the lock to prevent damage to the internal components of the lock as well as to the bicycle.

A free body analysis was performed to determine the required clamping force applied by the brakes to resist rotation from a large force applied on the pedal. This transmits maximum torque through the lowest gear ratio (1:1) to the rear wheel. The static friction created by the normal clamping force needs to be greater than this transmitted force in order to prevent rotation of the wheel. The required clamping force was found to be 150 lb.

That force was used as a benchmark to which all other components were designed. Finite element analysis was performed on each component based on steel or aluminum, depending on the part. The arms, pawl, ratchet, shaft, horseshoe, and kickstand are all made out of steel with safety factors of 2.5, 4, 3.5, 3.7, 2.2 and 3, respectively. The rest of the parts (excluding fasteners) are made out of aluminum. These include the case and the bicycle mounting features. The case has a
safety factor of 7.8, and the mounting features have safety factors of 3.2 (top) and 1.7 (bottom). The safety factor of the horseshoe is not a cause for concern due to its location on the bike which makes tampering difficult. There are other features designed into the lock to prevent excessive loading from reaching the arms, as this would also cause damage to the bicycle rim. These features include hard stops in the case, and a breakpoint in the kickstand.

**Key Advantages of Recommended Concept**

The biggest advantages of this design concept are its effortless engagement and its ease of transporting. Activation requires no more effort than normally expended when parking a bike. The kickstand is simply lowered and the bike is immobilized. The rider does not have to worry about finding something to ground the bike to (such as a bike rack). The rider also does not have to carry their cumbersome lock. The lock is estimated to weigh about the same as the lightest U-locks at around 2.5-3 lb, which does not represent a significant weight addition to the bicycle.

**Financial Issues**

In order to be competitive in the bicycle locking market the product should cost no more than $150. The projected unit cost is $80-120. The design is currently being analyzed to determine its cost. Other competitive and successful locking devices in the market range from $15 to $180. This product is aiming to have a build cost no more than $60 to $80 with a profit margin of about 30% to 50%. This means that the market price of the product should be $80 to $120.

**Recommended Improvements**

Replacing the key lock with an RFID system would increase consumer appeal and ease of use. The prospect of creating a locking system that combines electrical and mechanical components has been considered many times but has been put aside due to cost, space, and electrical issues. An unlocking solenoid coupled with a RFID electrical circuit, similar to a car key RFID, would greatly increase the ease of use, speed, and marketability of the product. Disengaging the lock would be a push button solution. Other improvements that are being considered include cost reduction efforts on many of the parts and the increased adaptability of the product for mounting onto all different types of bicycles.