EDSGN 100

Design Project #2

Final Report

Project: Re-Cycle

Introduction to Engineering Design
EDSGN 100 Section 024

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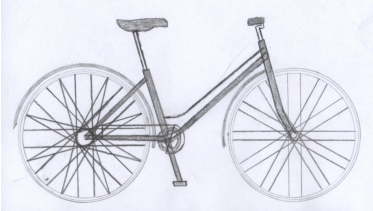

Submitted to Prof. Bilén
Date: 11/18/13

Executive Summary

The ultimate goal of our project was to make the University Park campus of The Pennsylvania State University more sustainable by utilizing aluminum and its properties. After research, consideration, and discussion, we decided to design a bicycle sharing system. Information was gathered from outside sources in order to gain an understanding of the necessary parts of the system. Throughout the process, we strived to create a system that increased campus sustainability while satisfying the needs of both the students and the local community.

Project: Re-Cycle

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1.0 Introduction

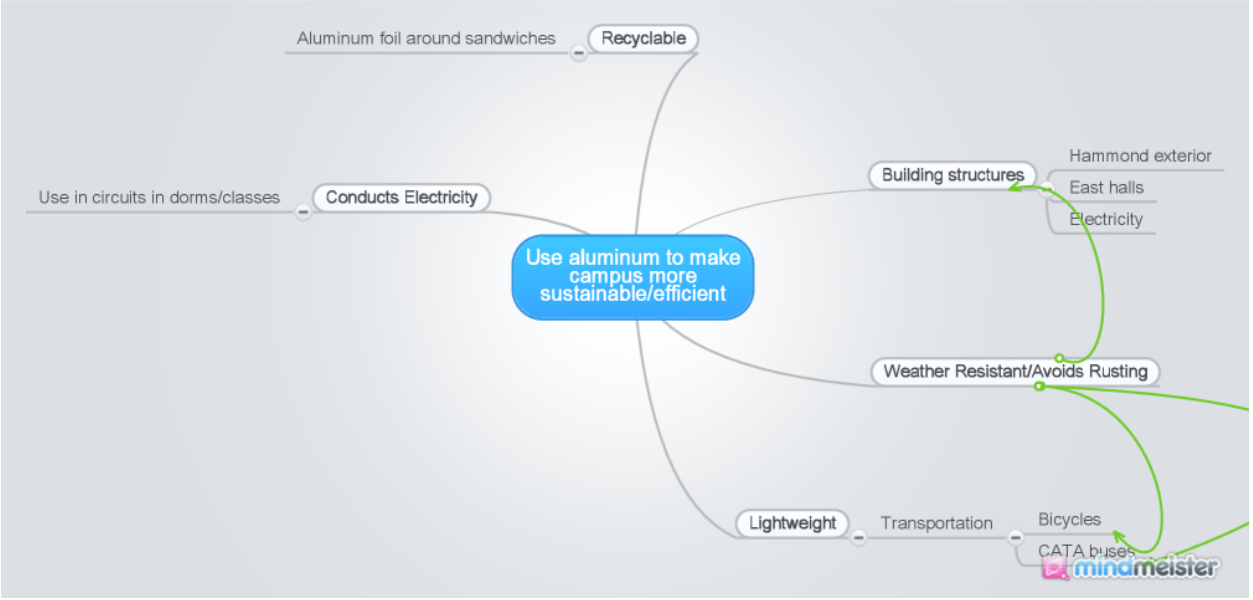
The problem addressed throughout this project was fostering sustainability and efficiency of the Penn State University campus using aluminum. As this was a very open-ended task, we created a more specific problem statement that pertains to our particular strategy for creating a more sustainable campus. In this preliminary design review, we outline our narrowing of our problem statement (Section 1), our customer needs collection and assessment (Section 2), the external research of other solutions to our problem (Section 3), and our development and selection of concepts (Section 4).

1.1 Initial Problem Statement

Make the campus of the Pennsylvania State University more sustainable and/or efficient by utilizing aluminum

1.1.1 Analysis/Exploration of Initial Problem Statement

Facing a very broad task, we felt the need to look at the problem in many different ways. What about the campus is inefficient? What could be made more sustainable? What are aluminum's properties and how might they be used in order to improve campus? These were the topics that we explored in our mindmap.



1.2 Revised Problem Statement

Make the campus more sustainable by utilizing aluminum in implementing a bicycle sharing system.

1.2.1 Goals/Implications of Revised Problem Statement

We felt that a bicycle sharing system would accomplish many things that would improve campus sustainability, such as:

- decreasing dependence on CATA buses, lowering university's oil consumption because of lessened reliance on buses, fewer greenhouse-gas emissions
- aluminum bikes are relatively low maintenance
- more cost-efficient for people to share bikes than to buy individual bikes
    - decreases bike theft opportunity (which has been a problem at Penn State)
- economically self-sustaining, will generate revenue once implemented (but will cost a lot to implement)
    - university doesn't have to pay CATA as much because the university will be less dependent on cross-campus automotive transportation

1.2.2 Importance of Aluminum

Once we decided to design a bicycle sharing system, we knew that we would be using aluminum in a couple different ways because of its useful properties. We planned on making the bikes themselves out of aluminum because aluminum is lightweight, durable, and strong. We also planned on making the kiosks and any additional (this is to be explained later in the project) bike racks out of aluminum because it requires little maintenance due to its durability in difficult weather conditions, which is ultimately what is necessary for the stations since they will be outside.

2.0 Customer Needs Assessment

We interviewed students around campus to develop a list of customer needs. We interviewed students because they are the group of people who would be using our product, so we figured they would provide us with the most valuable information. We tried to gain information from them about what they look for in bikes, any experiences they've had with bicycle sharing systems and any problems that may have been apparent, why they might not ride a bike around campus right now, and how they would prefer to pay for the privilege to ride a bicycle.

2.1 Weighting of Customer Needs

To develop this list, we asked very specific questions.They are as follows:

1. Why don't you ride a bike around campus?/Why don't you ride your bike more often?
2. Are you familiar with any bike rental/sharing systems? What do you like/dislike about them?
3. What do you look for in a bike?
4. How would you prefer to pay for such a system?

Table 1. Initial Customer Needs List for Payment Options Obtained from Individual Interviews

cheap
quick
many options
convenient

Table 2. Initial Customer Needs List for Bikes Obtained from Individual Interviews

cheap
lightweight
durable
aesthetically pleasing
easy to ride
comfortable

Based on the frequency of these needs being mentioned, we created a hierarchical list of needs

Table 1. Hierarchical Customer Needs List for Payment Options

1.cheap
2. quick
3. convenient
4. many options

Table 2. Hierarchical Customer Needs List for Bikes

1. cheap
2. light weight
3. easy to ride
4. comfortable
5. durable
6. aesthetically pleasing

3.0 External Search

Our external search began as soon as we decided to implement a bike sharing system on campus. This is because the idea came to us as a result of our experience with bike sharing systems (such as Capital Bikeshare in Washington DC). In terms of the overall system, there are many things to consider. To ensure ample consideration of all of these factors, we looked to the development of other bicycle sharing systems, specifically that at The University of Illinois at Urbana Champaign.

3.1 University of Illinois Bicycle Sharing

Since the University of Illinois is fairly similar to Penn State in terms of student population, it is an apt model off of which to base our bicycle sharing system. However, it is also important to keep in mind the differences in physical campus size, community urbanization, and culture in mind. In the feasibility study which was conducted at Illinois, they talk about the problems of previous bike sharing systems, the effect of a growing bike culture on the community, necessary infrastructure in bike sharing systems, and recommendations for planning of bike sharing systems.

3.1.1 Problems of Bike Sharing Systems of the Past

One of the major problems of early bike sharing systems was user accountability. This is because some of the first bike sharing systems were free for users, and there may or may not have been locking devices for the bikes. This led to a great amount of both theft and vandalism of the bikes. Furthermore, the maintenance of many of the early systems was carried out by volunteers who might not have had the time to devote to the project as paid counterparts might.

3.1.2 Effects on Community

There are a wide variety of stakeholders in a project of this magnitude. First, the target users of this system would be the students of Penn State. By implementing a bike sharing system, we would be changing the culture of the campus. Specifically, we would be encouraging bike culture, changing many students' behavior with regard to their methods of traversing campus. However, an extensive bicycle sharing system would also affect the State College community. With more bikes on the road (particularly downtown), anyone driving in that area will notice the change. Although our goal only has to do with making the campus more sustainable, it is important that we consider the far-reaching effects (both positive and negative) of a system such as this, for they extend beyond the borders of campus.

3.1.3 Necessary Infrastructure

One of the major problems reported with the Illinois system was the need for better biking infrastructure. Namely, conflicts often arose as a result of roads being shared by bikes and cars. While this could be solved by infrastructure such as bike paths, it was also often reported that many bikers and drivers were not aware of the rules of traffic when there are both bicycles and cars. This makes education an important part of implementation of a new large-scale bicycle sharing system. Another problem reported was that the existing bike paths on campus were old (some constructed over 30 years ago) and not maintained as well as they should have been. So, the development and maintenance of both on and off campus bike paths will be important pieces to consider. Lastly, infrastructure involving the parking/storage of the bikes will be necessary. One of the big problems reported in the Illinois system was a lack of indoor storage. This led to some deterioration and overall lack of protection of the bicycles. However, in our case, we will be using aluminum as the main material in both our bike and kiosk. Due to aluminum's innate ability to avoid rusting (actually it rusts very quickly but develops a protective layer around it once it rusts), it should be very durable and fairly easy to maintain.

3.2 Capital Bikeshare

This is the bicycle sharing system in Washington DC. Since it is a very different setting than that of State College, we could not base our system largely off of theirs. However, we did gain some more insight into the methods of payment and user accountability from this system. In the Capital Bikeshare system, when a person takes out a bike, a security deposit is taken from the account used to pay for using the bike. This way, if a person does not return the bicycle after a designated amount of time, they lose that money. This is a possible solution to the accountability problem seen in the bike sharing systems of the past.

3.3 Bike Locking Methods

There are many different ways that bikes have been locked in bike-sharing systems of the past. There have been some in which a code is entered in order to obtain a key which is used to unlock a specific bike. There are some systems, largely pioneered by ViaCycle, which allows people to lock and unlock bikes with a smartphone app. The main objective of these methods is obviously to provide security. However, in our case, due to the objectives of this project, there are also some other innate characteristics of Penn State and the campus that must be considered in creating the ideal bike locking component of this shared bicycle system (which will be discussed in Section 4.2).

4.0 Internal Search

We searched internally for solutions to many problems within our system. We decided the best way to generate concepts for a system would be to use the method of decomposition.

4.1 Concept Generation

4.1.1 Payment System

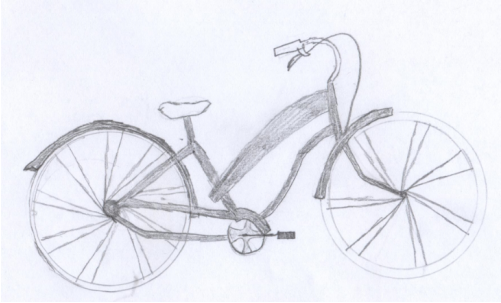
The generation method we felt would be most effective was decomposition. Decomposition addresses multiple aspects of a complex system. We identified components such as payment method, bike rack locations, bike type, and bike paths. Payment method and bike type were the two components we felt could be expanded into multiple, specific concepts. To develop specific concepts, we adhered to the 7 rules of IDEO Brainstorming: defer judgement, encourage wild ideas, build on the ideas of others, stay focused on the topic, one conversation at a time, be visual, and go for quantity. The first concept was “membership only”, which forces students to register for the service online with a flat rate, unlimited use contract. Our second idea was pay per ride, where students use LionCash to pay for each individual trip (based on the amount of time the bike is used). Our third concept was “levels membership”. Levels membership is like the campus meal plan in the respect that users buy a membership level based on how much they expect to use the service. The last concept generated was “cash toll booth”. This method works kind of like a toll booth, where cash is inserted and the user can take a bike.

4.1.2 Bike Type

We also generated concepts for bike type. We stuck to existing general bike types, because the point of our project is not to design a new innovative bike, but to design a system that encourages the bike culture of Penn State, in order to foster sustainability and efficiency. The four bike types were road bike, mountain bike, urban bike, and cruiser. When evaluating each of these, we decided that all of them would be made out of aluminum because that would make the bikes lightweight, strong, and fairly weather resistant. Furthermore, many bicycles are already made out of aluminum. Each bike has its own unique features, strengths and weaknesses. Our job was to decide which bike would best satisfy our customers' needs.

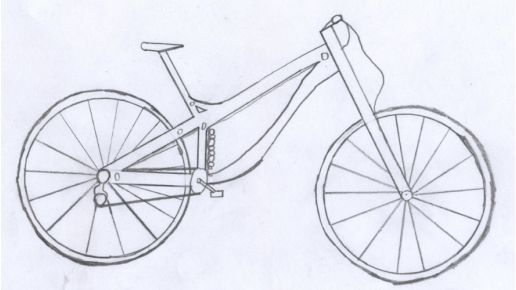
Concept A: Cruiser

The cruiser features high aesthetic appeal for a low price. The downside is that in being cheap, it is not of high quality. Also, cruisers are relatively heavy, and therefore hard to ride up hills.

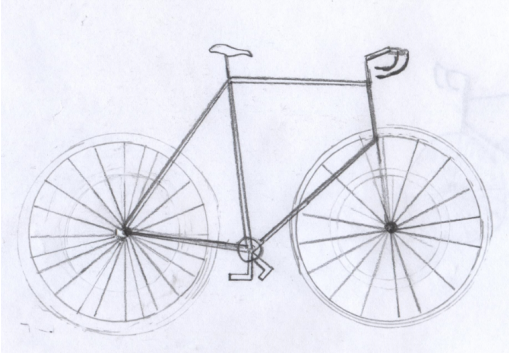


Concept B: Mountain Bike

The mountain bike features high quality suspension, durability, and aesthetics. It is relatively heavy, and expensive.

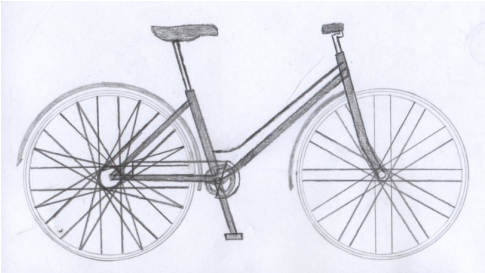


Concept C: Street Bike



The street bike is lightweight, fast, and durable. It is aesthetically pleasing as well. The only downside is that it is very expensive, and not as easily ridden for leisure.

Concept D: Urban Bike

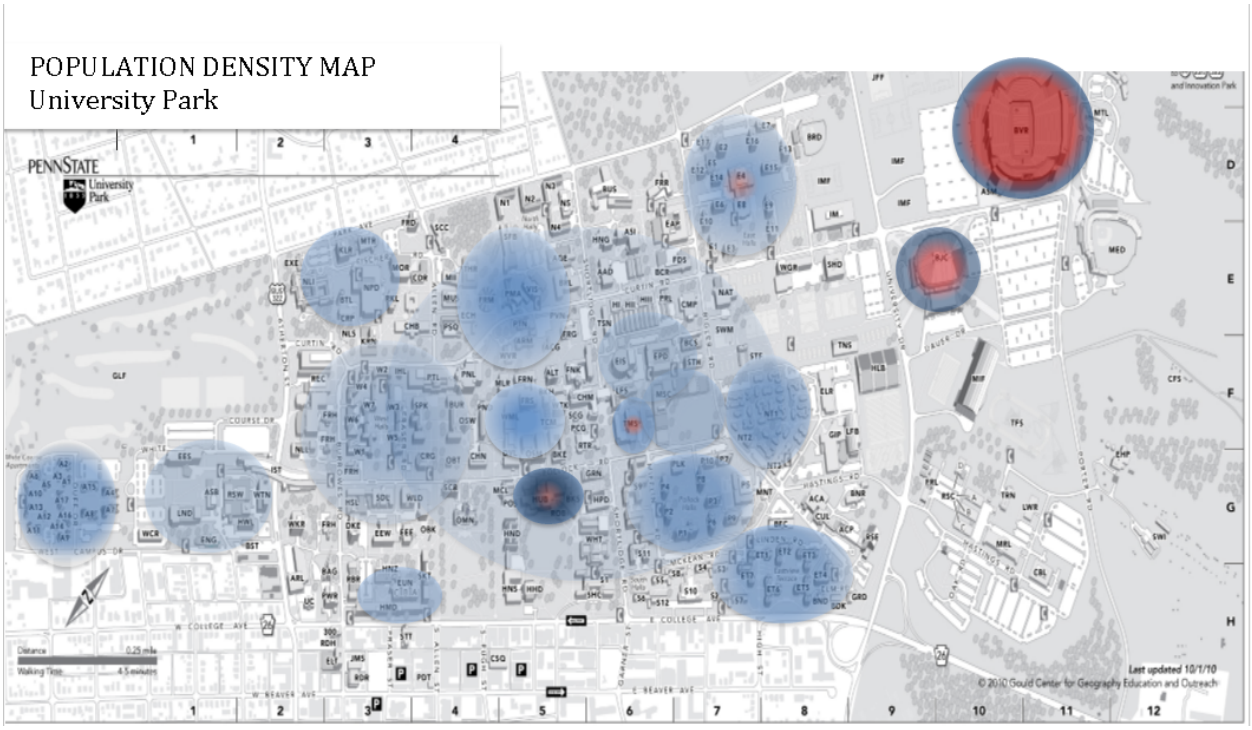


The urban bike is cheap without sacrificing quality, relatively light, and easy to ride. It is aesthetically pleasing as well. It is generally used for leisure or transport.

4.1.3 Paths, Kiosks, and Additional Bike Racks

We did not need a concept generation session for bike paths. Rather, we collected information about the buildings that held the most people for events or classes, and considered the foot traffic through certain buildings (such as the HUB-Robeson Center). This helped us later decide where we needed any additional bike racks on campus.

The map below shows where people concentrate during a typical week on campus. This helped us come up with our eventual map of bike kiosk placement. We generated this map based on our knowledge of campus happenings.



4.2 Concept Selection

The concepts were weighted against the following customer needs: cheap, convenient, having many options, and quick to use. Here are the results:

		A		B		C		D	
		Membership Only		Pay per Ride		Levels Membership		Cash Toll Booth	
	%	Score	Weighted	Score	Weighted	Score	Weighted	Score	Weighted
Cheap	30	4	1.2	2	0.6	5	1.5	2	0.6
Convenient	25	3	0.75	4	1	3	0.75	1	0.25
Options	15	1	0.15	1	0.15	3	0.45	1	0.15
Quick	30	4	1.2	4	1.2	4	1.2	1	0.3
	Total		3.3		2.95		3.9		1.3
	Continue	combine		combine		combine		no	

With these results, and with the customer need of "options" in mind, we decided to combine A, B, and C into one final payment concept. The bike rack will have a computer system, in which the user can register online for a levels plan, or a more expensive unlimited use plan. In order to include non-regular users, we will also implement a computer on each bike rack, where the user can use his or her lion cash for a time-based payment. However, an id+ card must be used, because there must be a way to identify a user who fails to return a bike. The exclusive use of an id+ card is a better security method than a

large security deposit placed on each user, such as that imposed by Capital Bikes.

As for the bikes, we rated each bike type against the customer needs of cheap, lightweight, durable, aesthetically pleasing, easy to ride, and comfortable. The results were as follows:

		A		B		C		D	
		Cruiser		Mountain		Street		Urban	
	%	Score	Weighted	Score	Weighted	Score	Weighted	Score	Weighted
cheap	20	5	1	3	0.6	2	0.4	4	0.8
lightweight	20	1	0.2	1	0.2	5	1	4	0.8
durable	10	3	0.3	4	0.4	4	0.4	3	0.3
aesthetically pleasir	10	5	0.5	3	0.3	3	0.3	4	0.4
easy to ride	20	3	0.6	2	0.4	5	1	4	0.8
comfortable	20	5	1	3	0.6	2	0.4	4	0.8
Total			3.6		2.5		3.5		3.9
Continue?		no		no		no		yes	

We decided to go on with the urban style bike, because it has the aesthetics of a cruiser, the ease of use of a street bike, and the durability of a mountain bike. It is a compromise of all customer needs. In order to give a bike target, we will model our bicycles after the 28 inch Nexus 3-Speed bike. It is a simple, aluminum urban bike that is lightweight and is a seven speed bike that will make it easier to pedal uphill, since campus is very hilly.

4.2.1 Target Specifications

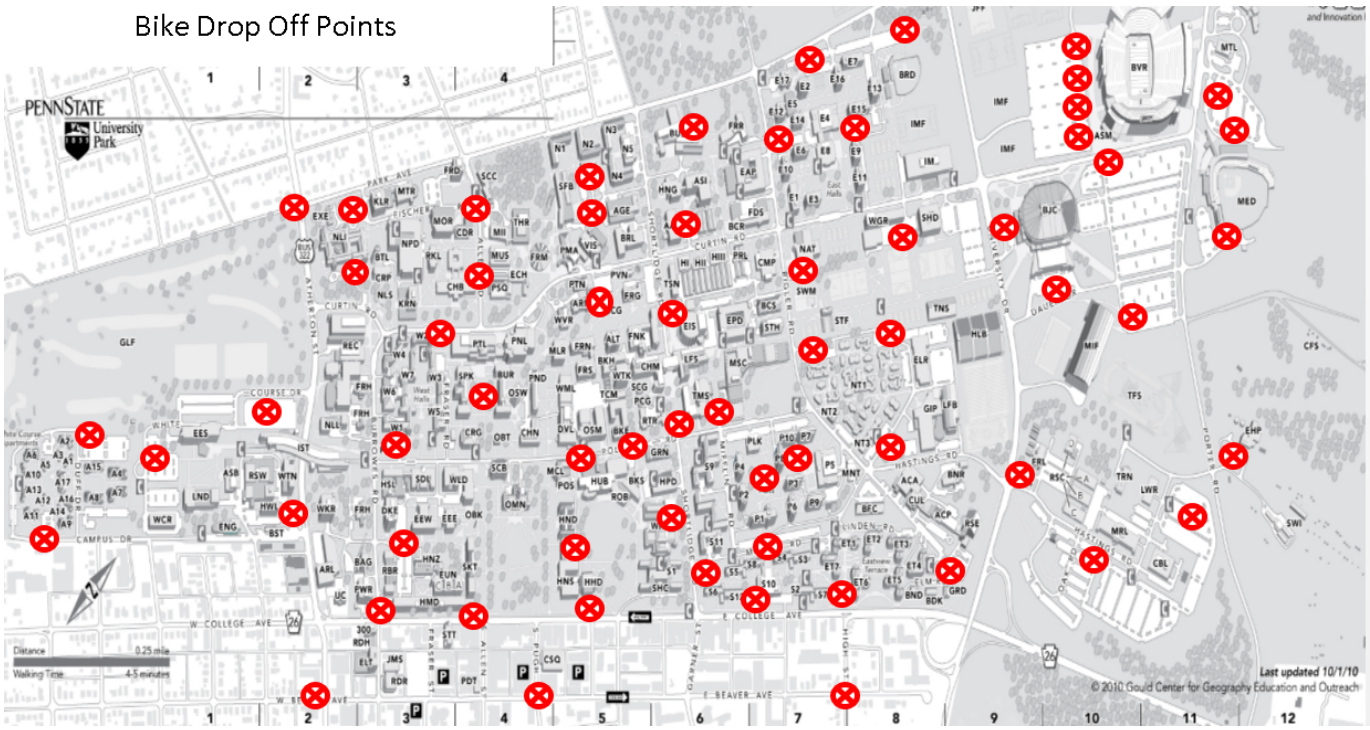
Since we are largely modeling our bicycle after the 28 inch Nexus 3-Speed bike, our target specifications are that of the that bike. We translated some of our qualitative customer needs into quantitative metrics. Next to the quantifiable metrics are corresponding customer needs in parentheses. Below are our target specifications for our bike.

	Ideal	Marginally acceptable
Unit price when bought in bulk	$60	$110
Weight (lightweight)	15 pounds	20 pounds
Durable	Made out of aluminum	N/A
Aesthetically pleasing	Blue and White, PSU theme	N/A
Speeds (easy to ride)	3-speed	N/A
Comfortable	Urban bicycle	N/A

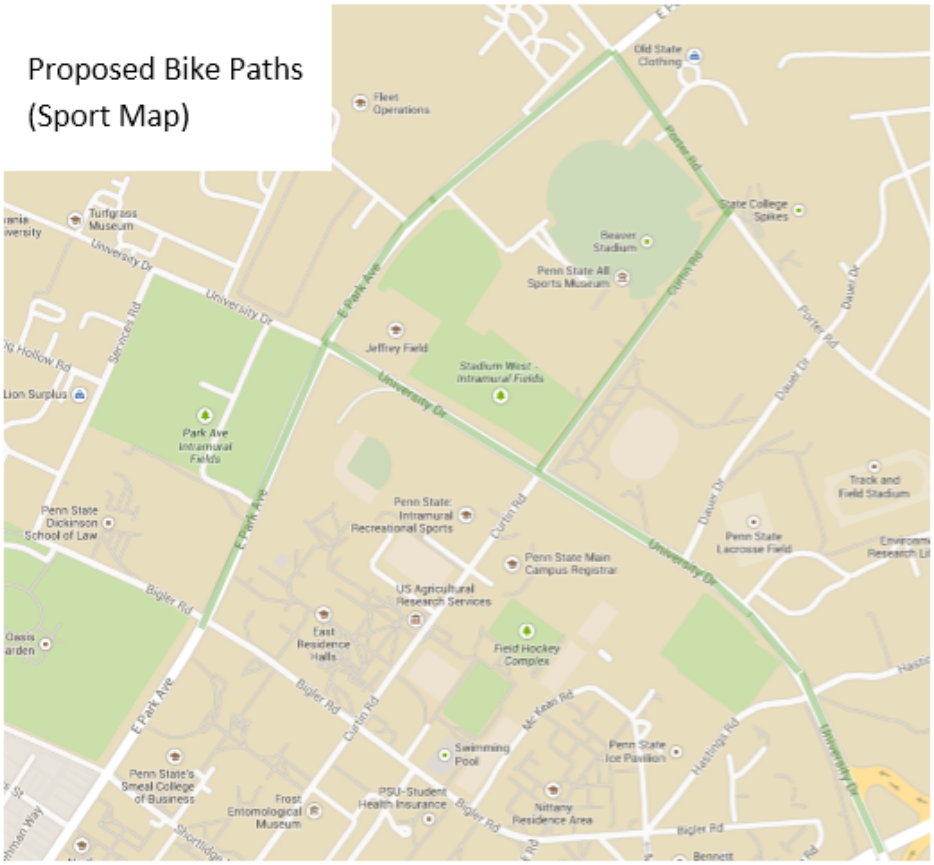
Our only other quantifiable target specifications for the project have to do with the total number of bikes and bike slots in the system. We gained these numbers as from our research on the bicycle sharing system at the University of Illinois at Urbana-Champaign. The total number of bikes in the system will be 1160 and the total number of bike slots will be 5800. There must be more slots than bikes in the system because there will not be a completely even student density throughout campus.

4.2.2 Large-Scale Implementation Concepts

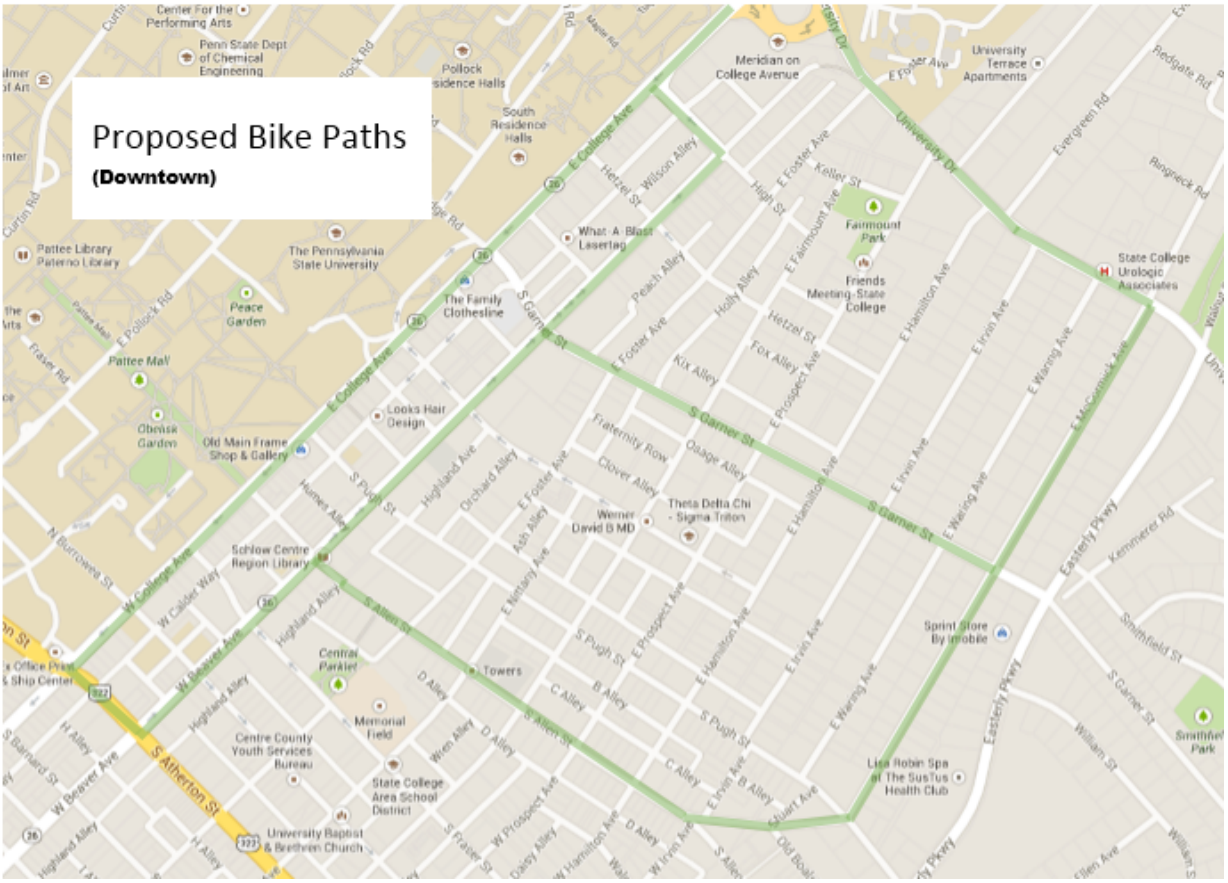
Although the selection matrices above deal with our concept on a unit basis (that is, the design of each bike station and bike), we still had to use our knowledge of campus and nearby off-campus areas combined with our population density data in order to design the actual system, locating the bike kiosks and bike paths that will be necessary in this system. Below we have the maps of the locations of the bike kiosks, the proposed bike path locations around the sports complex, on campus, and off campus.



Proposed Bike Paths
(Sport Map)



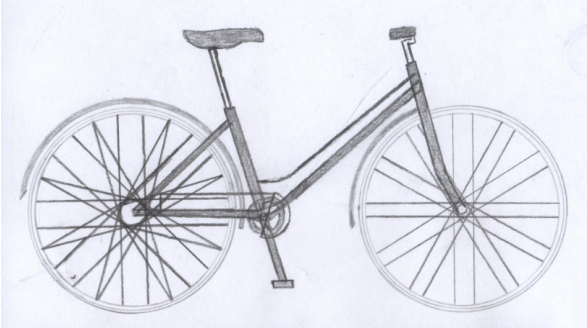
Proposed Bike Paths
(on campus)



4.2.3 Final Concepts for Bike and Rack/Station

As a result of our concept scoring, we chose to use an urban bicycle made out of aluminum. However, in order to go along with our bicycle locking mechanism, we had to alter the original plan slightly. First, each bike will be numbered (#0001 to #5800) clearly. Also, there will be a small loop attached to the rear wheel of each bike. This loop can be opened and closed at the kiosk closest to the bike. At any kiosk, the student swipes his/her id+ card. Next, the student enters the number of the bike that he/she wishes to use (any bike on the nearest rack with a visible number). The student, when taking a bike out, only needs to choose a bike number from the list of bikes on the screen (bikes in range of kiosk). The student does not need to designate that he/she wishes to unlock or lock the bike, because an already-locked bike doesn't need to be locked again. Thus, when a student chooses the bike number after swiping their id+ card, the bike unlocks and may be used. When the student wants to return the bike, all they need to do is place the padlock loop around a bike rack and swipe their id+ card. This is because when a person takes a bike out, they are associated with that bike's number, so when they swipe their card, the bike locks because the kiosk recognizes that this person already has a bike. This works with a short range signal from the kiosk, so that people can't lock bikes that are too far to even

see. After conducting research on different methods of remote controlling, we decided that bluetooth would make the most sense in our system because the kiosks would recognize the specific bikes that are within range of it. The kiosks could be connected to many bikes at once, and, from a maintenance perspective, if we see that a bike has been in range of one kiosk for a long time, we would check to see if it is broken or malfunctioning. Furthermore, if a bike is not in range of any of the kiosks, we could conclude that it is lost and hold the last person to unlock that bike accountable. Because this bluetooth connectivity takes a small amount of electricity, we will have solar panels on the bikes so that they can accumulate the necessary energy to lock and unlock. Since the main locking mechanism is attached to the bikes, we will be able to utilize existing bike racks on campus. However, since we are trying to further encourage bike culture, we will need additional bike racks. Furthermore, we will need a kiosk at every bike station. In the end, we feel that this locking system fosters both the freedom of bicycle sharing along with user accountability, as a person is temporarily identified with a bike number.

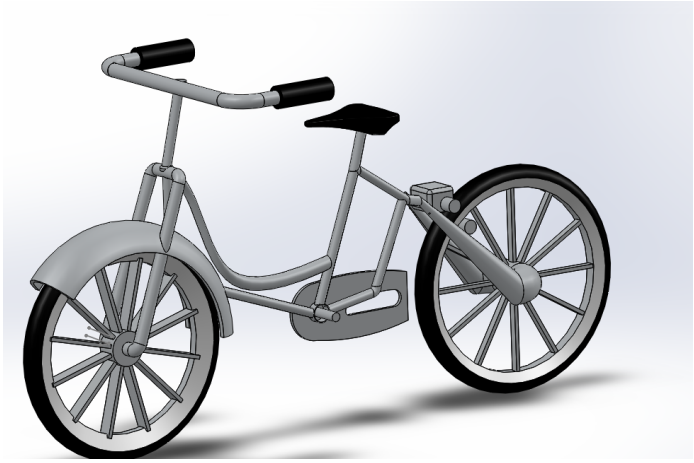


5.0 Review of Design Features

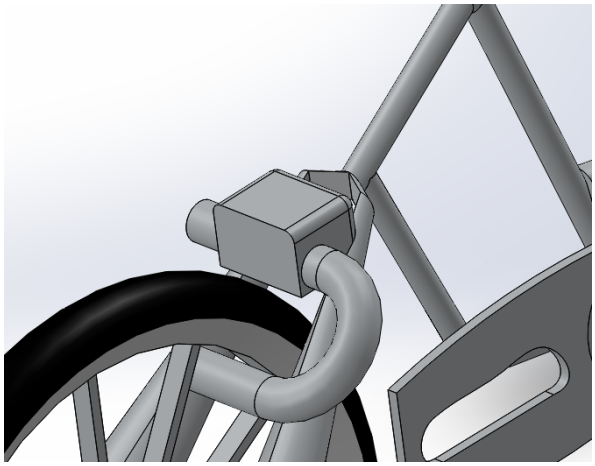
A brief outline of our design features is as follows:

- 1160 urban bicycles made out of aluminum, modeled after 28 inch Nexus 3-speed bike
    - loop on rear wheel of bike that closes when locked, opens when unlocked
        - bluetooth connectivity, powered by small solar panel on top of padlock
- New bike paths on frequently crowded streets on and off campus
- New bike racks, made of aluminum, in addition to already-existing ones
- Kiosks, made of aluminum, and bike parking lots near the most frequented places on and off campus
- Both registered members (for either one of the levels or for unlimited use) and one-time users can take out a bike

Below is a 3-D model of our bike with locking mechanism on the rear wheel (made in SolidWorks):



Below is a close-up of the locking mechanism on the rear wheel, when locked:



5.1 Limitations of Design

One of the biggest limitations of our design was an inability to accurately predict the total cost of the project. We can guess that producing the bikes will cost around $127,600 if they meet our marginally acceptable price. However, as could be seen in the University of Illinois' bicycle sharing system, it can be very difficult to accurately estimate the total cost of a system with so many parts, especially when there is construction (of bike paths, in this case) involved. As a result of this weakness, it is hard to say exactly how much students would be charged for the using the system, as those two pieces of information depend on each other. Another weakness of our design stemmed from the inability to run a trial of our system. It is certainly not uncommon though, to not have done testing of the functioning of an

entire system before the system is implemented. Rather, there may be trial periods in which the user implementing the system makes a short-term commitment to use of the system. In our case, our research on the University of Illinois acted as our testing. We learned from the shortcomings of their systems of the past, and modeled some of the aspects of our design after what succeeded in their design.

5.2 Unique Features

The most unique feature of our design is probably the locking mechanism, a padlock that is closed through bluetooth connection to a kiosk. When considering the locking method, we had to address bike security and user accountability. Since every bike has a number, and a person is associated with that bike number until they return it, we address user accountability. Since the locking mechanism both locks around a bike rack and keeps the rear wheel from spinning, it decreases the chances of bike theft in that if someone just locks a bike without it being around a bike rack, the bike cannot be used. Another consequence of utilizing bluetooth technology is its ability to recognize specifically which bikes are within its connectivity area. A computer can view the information from the kiosks so that daily inspection might be able to be done by one person sitting down. As a result, maintenance is streamlined as a bike that has been near the same kiosk for days may be broken or malfunctioning. If it is determined that the bike is broken, the last student to have taken out that bike can be held responsible. Furthermore, if a bike is out of range of a kiosk for a long time, we may conclude that the bike is missing and hold the last student to use it responsible. Although the main goal of the project is to create a more sustainable option for cross-campus transportation, user accountability and security are two vital aspects in achieving the ultimate goal of increasing campus sustainability.

6.0 Description of Operation Design

We have outlined a 6-step system for student use:

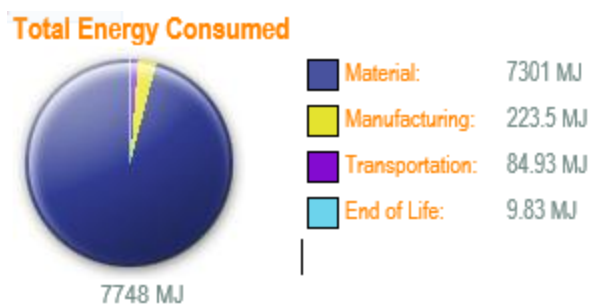
1. register online for membership (recommended, but not necessary)
2. swipe id+ card in kiosk
3. choose bike number
4. to return bike, pull into bike parking lot, within range of bluetooth kiosk
5. place rear wheel padlock around bike rack
6. swipe id+ card to confirm safe return

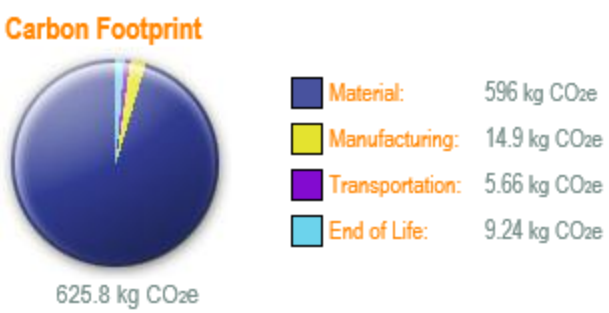
As can be seen above, a student does not have to designate whether he/she wants to lock or unlock a bike. This is because, if the student has no bikes rented, they are presented the list of bikes available for use when they swipe their id+ card. Once they choose a bike, it simply unlocks because an already-locked bike does not need to be locked again. Furthermore, for the return process, all a student has to do is line up the locking mechanism with a bike rack and swipe their id+ card because the bike

that they were using has a number that is associated with the student id number. This creates a quick process for student rentals because, ultimately, many students would use this bicycle share when they need to go across the campus quickly, perhaps between classes; thus, anything that could make the process quicker would likely be appreciated by the student.

7.0 Life Cycle Analysis

In order to conduct a life cycle analysis, we first did some research to find which aluminum alloys are commonly used in bicycle frames. The two common alloys were Aluminum 6061 and 7005. After reading about each of them, we found that they share many of the same physical properties, but the 7005 alloy is slightly more dense, usually less ductile, slightly stronger, and usually more expensive. Based on this, we decided that the 6061 alloy would be best for our purposes, since the bikes' weight and cost were two of our more important needs for the bikes. Once we decided to use the 6061 aluminum alloy, we used the SolidWorks sustainability feature to analyze the effects of manufacturing the bike on the environment. Below are graphs generated by SolidWorks showing the environmental impacts of manufacturing the bike out of aluminum 6061-T6, a very common alloy used in bike production.





Since aluminum is commonly used in bicycles, our material use is not the most unique part of our overall design. However, aluminum is important in creating overall sustainability. Its innate recyclability and durability through many weather conditions make it a vital material in not only our bicycle, but our bike racks and kiosks as well.

8.0 Summary and Conclusions

Overall, we feel that our bicycle sharing system would be a success if implemented. The individual bikes were tailored to both the explicitly-stated customer needs and the implicit expectations of a functioning bicycle. We give the user options and convenience in terms of payment and operation. Our bike paths make bike culture a more integrated part of the campus and downtown State College. We feel that our system does make Penn State more sustainable, both environmentally and economically.

Resources

http://icap.sustainability.illinois.edu/files/project/109/Bicycle%20Sharing%20Feasibility%20Study%20Final%2011-30-12.pdf
http://www.openideo.com/fieldnotes/openideo-team-notes/seven-tips-on-better-brainstorming
http://capitalbikeshare.com/
http://www.onbikeshare.com/bikeshare-university/universitybikeshare.php
http://www.alibaba.com/
http://www.pcmag.com/article2/0,2817,2427234,00.asp