Bike to Basics: A Cargo Bicycle Design for Short-distance Commuting

Cong Yao

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Bike to Basics:
A Cargo Bicycle Design for Short-distance Commuting

By
Cong Yao

MFA

ROCHESTER INSTITUTE
OF TECHNOLOGY

School of Design
College of Image Art and Science

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"When I see an adult on a bicycle I do not despair for the future of the human race." —H.G. Wells
Approvals

Stan Rickel, Chief Advisor
Associate Professor
Industrial Design Graduate Director
585-475-4745 / srrfaa@rit.edu
Signature: ___________________________ Date:___________________

Kim Sherman, Committee Member
Senior Lecturer, Industrial Design
585-746-4643 / klsfaa@rit.edu
Signature: ___________________________ Date:___________________

Jon Schull, Committee Member
Assistant Professor, Director, Center for Student Innovation
585-738-6696 / Jon.Schull@rit.edu
Signature: ___________________________ Date:___________________
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Abstract

Cycling plays an important role in our modern transportation system. It is simple, efficient and affordable. Bike is human powered, lightweight and relatively easy to manufacture compared to other vehicles. There are many companies dedicated to producing different types of bicycles for the market and there are many bicycle builders who craft authentic unique bicycles by hand.

For my thesis project, I studied the history of the bicycle in order to understand the philosophy of bicycling. I addressed many types of problems in this field and did field research in bike shops and with bicycle enthusiasts. I learned many techniques for building high-functioning prototypes from bike builders and bike mechanics. I also visited Rochester Commuting Bike and the Rochester Public Market to do field research and scenario map design. I found many problems that need to be solved in this area and I designed three concepts with actual-scale prototypes to explore.

Not all of the concepts functioned well. My techniques for bicycle building got better and better over the course of the design process. I got much valuable feedback from my professors, committee members and other industrial designers that helped me to achieve the final design. All of the welding parts of my final concept including frame, wheelie bar and saddle support were done by myself with the help of my professors and the teachers at Rochester Arc & Flame Center. I collected bicycle components and assembled the bicycle in the Industrial Design studio of RIT.
Introduction

There are different types of bicycles made for different types of users. Bike enthusiasts may spend thousands of dollars on a racing bike made of carbon-fiber for racing games or exercise. Casual riders may choose a fixed-gear/single-gear bicycle without brakes or a gear-shifting system for a more exciting, fun and challenging experience. Those who commute to work every day might be interested in cargo bicycles.

A bicycle is one of the smartest products ever designed. There are several generations of bicycle designers and bicycle manufactures that made many famous landmark bicycles that permanently changed our lifestyle. Bicycles have never faded out of fashion even as more and more successful methods of transportation have developed over the years. Riding a bicycle is becoming a new lifestyle that helps people achieve a neutral carbon footprint environment. Compared to using transportation methods such as motorcycles, cars and trains, people choose to ride bikes to achieve a healthy and economical commuting experience.

When the chain-driven bicycle was invented, the designer never would have believed that bicycles would still be so popular despite the emergence of cars and airplanes with the advent of the 20th century. For example, according to the New York City
Department of Health, 236,000 New Yorkers rode their bikes every day in 2010 and the number is still increasing dramatically. According to Transportation Alternatives, the number increased 28 percent from 185,000 the year before. More and more people accept and embrace the philosophy of cycling because of its fundamental nature, which is energetic, environmentally friendly, confident and optimistic. Additionally, bicycles play an important role for people and organizations to achieve a carbon neutral environment.

But things aren’t always what they seem to be. Many bicycle designs on the market have design flaws that directly affect users’ health, including causing back and shoulder soreness, muscle pain and genital numbness. In addition, a bad welding joint or low manufacturing quality of any metal part may cause a component to rust, which could eventually end the life cycle of a bike.

I was born in China and I lived there for more than 20 years. I rode a bike to commute from home to school every day from the age of 15. Most of the bicycle lanes in China are wider than 15 feet and they are spread all over the city. My father bought me my very first mountain bike for my birthday. I was obsessed with the mechanism of the bike and the simplicity of the construction. I was always trying to fix my bike by myself when it had a flat tire or a loose brake.

1 See the New York Times, April 26, 2010, More than 200,000 a Day Now Cycling, Data Suggests, especially Chapter 1
In this thesis, I will apply my industrial design skills and methods to explore this sophisticated product and solve the problems of the bike with better solutions.

What Is a Bicycle and What Is a Utility Bicycle?

A bicycle is a two-wheeled vehicle that a person rides by pushing on foot pedals. A utility bicycle is a bicycle built for short-distance commuting, transporting cargo or merchandise, delivery and general urban transport. As opposed to the road bike and mountain bike, most of the utility bicycle designers focus on a more practical design instead of one for competition or racing.

Utility bikes are very popular both in developing countries and in developed countries where the price of a utility bicycle is affordable for most families. A utility bicycle is built for a more reliable and safe journey without too much concern for the weight of the bike; most of them can carry a certain amount of cargo or even a small child when equipped with a child seat. In the United States, people use them as hip human-powered transporting devices for going to work, shopping, transporting goods and merchandise or exercising.

A Brief History of the Bicycle

The history of the bicycle can be divided into two significant periods: the period of a “running machine” without pedals, and the era of the modern bicycle with pedals. A
plethora of designers made significant contributions to the development of the bike through different processes and different methods. They are from different fields with unique points of view, including physicists, painters, designers, sociologists, etc.

In the early history of human-powered transportation devices, there were many examples of imperfect attempts at harnessing human strength to power a transportation device before the invention of the bicycle, which is a brilliant and perhaps the optimum design to use muscle power.

In the early seventeenth century, many boats used the muscle power of many men, likely criminals, chained to benches, according to a drawing in the British Museum by Dave Wilson. There are hundreds of men pushing fifty-four sweeps on a boat arranged in 30 rows led by a man with a drum installed on the front side of the boat. They are mostly using arm, back and leg muscles. While not like boat sweeping, bicycle is a perfect example for using muscle power.

In 1816, Baron Karl von Drais from Mannheim built a "running machine" with two wheels for easing the tension of the horse shortage in central Europe. From the drawing of Joachim Lessing, the Draisienne has obvious utility purpose such as two suitcases on both sides of the front wheel and a cargo carrier in the back. In the 1860s, Pierre Michaus and Pierre Lallement both made great contributions to the

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2 See Bicycle Science by David, G. W., especially page 5, Chapter 1
bicycle with the development of the pedals, one of the most significant improvements in the history of the bicycle.³

In the United States, after the bicycle boom from the 1890s up to the Second World War, the bicycle's price dropped dramatically and many people at that time purchased bicycles for utility reasons. During that time, the safety bicycle invented in 1990s by English engineers grew rapidly and became more popular than the penny-farthing along with a lot of developments and improvements. In other developing countries like India, China and Netherlands, utility bicycles remain very popular today.

As a simple and elegant universal design, the classic diamond frame remains popular in most countries today. It is worth pointing out that in 1962 the Moulton Company's factory at Bradford-on-Avon in the United Kingdom/England started the production of the Moulton bicycle, designed by Dr. Alex Moulton.⁴ As the first innovation after the safety bicycle, the Moulton bicycle had many utility purposes: two small 16-inch wheels designed for less rolling resistance and greater acceleration; a cargo holder for transporting goods or merchandise; and a unique F-frame without a top tube, making it easier for people with mobility limitations to mount. In the 1990s, new technologies such as a navigation system, a new gearing and brake system, electronic

³ See Bicycle Science by David, G. W., especially page 10, Chapter 1
⁴ See the Heritage section on this page, http://www.moultonbicycles.co.uk/heritage.html
assistance and lighter materials brought bicycles to a new stage.

**Current Utility Bicycle Designs in the Market**

There are many types of bicycles that can be used for utility purposes. People can also find many different ways to customize their bicycle with accessories to fit their needs. There are six utility bicycle designs in particular that inspired me.

**Sohrab Cycles**

Sohrab Cycles is a traditional English roadster produced in Pakistan. The first Sohrab bicycle was developed in 1952. The weight of a 2012 Sohrab Standard Roadster Single Bar bicycle is 15-21kg. It has a steel-made tubing diamond frame with two 16- to 24-inch wheels and two rim brakes. This type of bicycle is very popular in developing countries. They are affordable, reliable and comfortable for commuting. There is a cargo carrier on the back of the saddle that can carry people or cargo. This bicycle is loaded with a single rear gear without any gear-shifting systems. Because of the solid build, this bike tends to be more robust, unbreakable, affordable, universal and relatively heavy because of its steel-made frame.

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Metrofiets Cargo Bike

Metrofiets, LLC, is collaboration between James Nichols & Phillip Ross. The classic style of bicycles in the 1930s and ’40s inspired Nichols and Ross to begin producing Metrofiets in 2007. Over time, they have developed collaborative relationships with a collection of dedicated artisans and craftspeople, their sole goal being to create the most beautiful, functional cargo bikes ever made. Because their bicycles are all handmade, they are expensive. The price tag of this particular cargo bike is $3695.00

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6 See About section from their website, http://www.metrofiets.com/who
U.S.

Donky Bike

The Donky bike was developed as a prototype. When it was being tested, two 20-inch wheels were selected to keep the footprint compact. The square-section beam carries the entire load and offers a versatile platform for front and rear attachments. The frame geometry and gearing gives a relaxed, efficient ride. The idea took a while to reach the production stage but it works very well for the American
market because it's cost-effective and well-designed mechanic.

Batavus Utility Bike

Batavus is a Dutch bicycle manufacturer that has produced many types of European city bikes since 1905. In 2010, The Batavus Utility Bike designed by VanBerlo won an IF gold award based on a paperclip shape frame. The design is simple, unique and sophisticated. There is a cargo carrier installed in the front that is permanently joined with the bike itself. People can put a basket, cargo or luggage in the front. The new 2012 Batavus Utility Bike is beautifully crafted with an aluminum frame, front basket
and two 26-inch wheels.\textsuperscript{7}

\textbf{Moulton TSR 2}

Moulton, founded by Dr. Alex Moulton in 1962, produced different kinds of small wheel bicycles that led to the first innovation of the utility bike since the safety bike was invented in 1885. In 2012, the Moulton TSR 2 weighed 26.4 lbs with a new Sturmey-Archer "kick-shift" two-speed gear and two 20-inch wheels.\textsuperscript{8} The front and

\textsuperscript{7} See Batavus Utility Bicycle from Dezen Magazine (3 March 2010) written by VanBerlo, especially paragraph 4

\textsuperscript{8} See Heritage section and The Originator section from the website of Moulton Bicycle Company, http://www.moultonbicycles.co.uk/heritage.html
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rear bag carrier is optional but well-crafted and perfectly fit. The bike itself is very beautifully designed. This bike’s frame is constructed with multiple thin tubes instead of a 1-inch aluminum tube. People can put it into the trunk of a car easily without having to disassemble the bicycle.

Long John Bike

The Velorbis Long John bicycle is a transport bike with an extraordinarily long-wheel base that can carry a huge load, but can still squeeze through traffic with ease. In order to carry considerably more load than a traditional 2-wheel bicycle, the design and ergonomics require a long-wheel base structure where the front wheel is steered via a linkage. Bicycles such as the Long John position the carrier extremely low, making them very stable with large loads.


**Why Design It?**

**The Benefits**

1. A utility bicycle has great potential in urban transporting because of its affordable, environmental friendly, practical and functional features. Riding a bike for commuting is a symbol of a healthy, confident and optimistic living philosophy. Because of its utility purpose, the overall design should follow the “Ten Principles for Good Design”¹⁰ introduced by Dieter Rams, a German industrial designer closely associated with the consumer products company Braun and the Functionalist school of industrial design.

2. Human-powered vehicles are more environmentally friendly than self-propelled motor vehicles. A bicycle doesn’t consume any fuel and therefore produces zero carbon footprint. A lot of campuses and companies are trying to achieve a neutral carbon footprint by encouraging people to ride bicycles instead of driving motor vehicles.

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¹⁰ See About Vitsoe section of his website, https://www.vitsoe.com/us/about/good-design
3. More than 40% of all car trips made in America are less than two miles\textsuperscript{11}; these could easily be done by riding a bicycle. Additionally, commuting to work by bike is clearly more affordable because of its low maintenance cost.

4. Once people get out of their cars and start to ride their unique, well-crafted and comfortable bikes, they will find that the experience of riding a bike is full of fun. Cycling is one of the best ways for people to achieve good health and fitness. What's more, “research continues to prove the strong link between cycling and improvements to men's mental health”, said by professor Adrian Bauman from University of Sydney.\textsuperscript{12}

5. Most of the utility bicycles feature an upright mounting position for better vision and a more comfortable riding posture.

The Problems

1. Cargo transporting is a classic feature of a utility bicycle. The problem of the cargo holder will be discussed in two cases in terms of its installation position:

   that of the cargo holder installed in the front and that of the cargo holder dragged behind the bicycle or installed in the back. In the case of the cargo

\textsuperscript{12} Please see section 1“it’s time to get the mo’s moving”, especially paragraph 3-5
carrier being installed in front, it becomes more challenging for people to fully
control the bicycle as the cargo gets heavier. In the case of the cargo holder
dragged or installed in the back, riders won’t be able to pay attention to the cargo
at all times.

2. Many studies have been conducted about the effect of biking on a male sexual
function. In Cincinnati, Ohio, the National Institute for Occupational Safety and
Health (NIOSH) did a research study on bicycling police patrol units. On average,
each bicycle policeman spends more than five hours in the saddle every day.
Almost all of them experienced genital numbness from time to time. Besides that,
NIOSH found that females also experienced decreased genital sensation after
cycling.

Sheldon Brown who is an American recognized bicycle expert stated on his
website (www.sheldonbrown.com) that sexual function is not the only physical
effect of riding a bicycle. Poor cycling posture can cause back pain, knee problems
and even injury because of rigid bones. The material, width, angle and height of
the saddle also greatly affect a rider’s shoulders, thighs and wrists. A good riding
posture is different from a good sitting or standing posture. A posture that is
comfortable for sitting still will not necessarily be comfortable while riding a
bicycle. A proper cycling posture must facilitate the pedaling action, and also

\[13\] See NIOSH Studies section, page 3, Non-nose Saddles for Preventing Genital
Numbness and Sexual Dysfunction from Occupational Bicycling by Steven M. Schrader,
Ph.D.
must enable the rider to cope with the jolts that result from road irregularities. Many inexperienced cyclists adopt a posture that allows their upper bodies to be supported entirely by their bones.

3. For comfort and utility purposes, recumbent bicycles with a saddle with back support greatly decreases saddle pain, and a laid-back reclining position offers a lower riding posture that greatly increases braking and stopping capabilities and allows a higher speed. But unlike the higher position of the saddle on the safety bike, the lower position results in a bad sight angle at sharp corners that is unsafe in an urban environment. It is also a bit more difficult to glance back when riding a recumbent bike.

4. Safety issues including cycling safety and bicycle maintenance are particularly critical in an urban circumstance. Based on a report from the NYC Department of Transportation, from October 1 to December 31, 2011 in Manhattan¹⁴ there were 258 accidents involving bicycles, pedestrians and vehicles. A large number of drivers choose to ignore bicycles and riders due to their low threat on the road. On the other hand, the bicycle rider involved in a collision is often unable to see the overall traffic situation due to narrow peripheral vision. In addition, most bicycles are built without a logical and refined exterior lighting design, which is

¹⁴ See Bicycle Crash Data section from New York City DOT official website on the following page: http://www.nyc.gov/html/dot/html/bicyclists/bikestats.shtml
5. This sketch notes the area that I was interested in studying/researching based on what I learned from the research. The two axes indicate the quantity of Utility to Fun and Cost-effectiveness to Cost-ineffectiveness.

Research Content

Introduction

The research process had two stages: interviews and field research. In terms of non-threatening circumstances, I learned about what motivates respondents, what is important to them and what they want. Each of the interviews lasted about one hour.
I drove the conversation with questions and I mainly focused on personal riding experiences and cargo transporting experiences. The interviews were designed to capture data that will be used to understand the problems, user experiences and the market. In total, I interviewed seven bicycle enthusiasts who have both cargo and transporting experiences. This information informed the design of my bicycle.

The field research involved going to Rochester Community Bikes in Rochester, New York. Rochester Community Bikes accepts any and all types of bikes, both children’s and adult. Bikes with special value are evaluated and sometimes sold, with the proceeds going directly back into the program to purchase parts, supplies and tools, thus enabling their work to continue. They also donate fully functional bikes to people who need them. I talked to the manager and mechanics about how they determine which the best bike is for each individual.

Interviews of Bike Enthusiasts

1. Mike Robinson, 25 years old, Bachelor’s Degree, lives in Shanghai

   Mike has considered himself a bike enthusiast ever since he bought his first Giant racing bike made of carbon fiber material. He also collects lots of accessories for customizing his bike including different types of tires for different weather conditions; many types of steering bars; and saddles in different materials, colors and scales. He has to drive to work every day instead of riding a bicycle because he lives too far from his place of employment. However, he brings his bike to
parks, racing tracks and the countryside to exercise with his friends and family.

He also has two single-gear bicycles because he loves the simplicity and robust build of this particular type. “Those bikes never break or drop you off on the road. They last forever,” he said. He does most of the maintenance himself for all of his single-gear and racing bicycles. One of his friends had a bicycle store he visited frequently for regular maintenance of his bicycles. He also enjoys carrying bags or cargos, and installing a cargo carrier. He likes the carrier installed in the back instead of in the front saying, “Heavy bags may affect the steering depending on how you install the cargo rack.” Mike is planning to move closer to his company next year so that he can ride a bike to work.

2. Jongsoo Kim, 29 years old, Master’s Degree, lives in Rochester, NY

Kim is a graduate candidate student from RIT. He started to commute to school by riding his bicycle a year ago. Although the mountain bike he has is from Wal-Mart and cost only $98.99 U.S., he has been very satisfied with its performance. His bicycle has a full gear-shifting system and a rear disk brake installed in the factory. He believes the purchase was a great deal for a full package built in such a solid way. But the gears and brakes have started to rust and therefore have generated a lot of friction between the chain and the gear since last winter. He brought it to a local bike store, where a mechanic talked him through removing the gear-shifting system and put lubricant on the chain. It
works even better now since there are no hills on the way to school. Kim is also planning to trade in his mountain bike for a single-gear aluminum road bike frame, which is lighter, faster and easier to disassemble to fit into his car better.

Kim packs his computer in his backpack instead of putting it on a cargo rack. He was thinking about getting a used cargo carrier from a local store and installing it in the front, but he was worried that heavy cargo would add weight to the steering bar, which might make it harder for him to balance.

3. Chen Zhu, 39 years old, Master’s Degree Candidate, lives in San Francisco, CA

Chen is obsessed with collecting human-powered commuting tools just for fun. He owns two three-wheel scooters, three fixed-gear road bikes and several skateboards. He loves leather saddles made by Brooks England, one of the most famous saddle manufactures in the world. He had a local painting studio help him sandblast the paint off one bicycle frame and he redesigned it with different colors, finishes and materials. All of his skateboards and scooters are toys that are collectables for him. He has a lot of fun with them and shares his new designs with friends. He also posts pictures and sketches he makes online. He recently enrolled in a gas metal arc welding studio class to learn how to build a bicycle himself. At the time of the interview, Chen Zhu was planning on purchasing used welding tools to turn his garage into a welding studio.
Chen Zhu loves the idea of transporting cargo using human-powered tools. He is very interested in how to design a cargo rack that can fit on any size bicycle but still be capable of carrying heavy cargo.

4. **Alex Dennison, 26 years old, Bachelor’s Degree, lives in Boston**

Alex rides his bike one mile to work every day. He has a 1993 Trek road bike with a customized handmade cargo rack made of maple wood installed on the back of his bicycle. He can’t put all of his stuff in his backpack because of the weight of his backpack and his bad back. He tried to install a cargo carrier in the front but found it very uncomfortable to control the balance.

He’s been looking for a cargo bicycle or a better way to carrying his cargo on his bike for a while. He tried several pull-behind cargo trailers but none of them were ideal for him. The cargo trailer made his bike longer, heavier and less appealing.

5. **Ming Lee, 55 years old, Doctorate Degree, lives in Beijing**

Ming is a graphic design professor at North China University of Technology. He has been living in Beijing for 20 years with his family. His apartment is located in one of the buildings on campus. He commutes to work using a Fenghuang utility bicycle that he bought 15 years ago. His bicycle is built in a solid way just like Sohrab Cycles. His bike doesn’t have a gear-shifting system or a disk brake, but he still manages to ride it to work every day. It is very frustrating for him to find rust
on the gears or chain because it dramatically increases the friction. He installed a
cargo carrier above the rear wheel for loading his luggage. He carries books,
computers, his lunch and one projector.

**Scenarios Research**

**Introduction**

I designed two route scenarios to help me to understand the problems faced by
cargo bicycle users on their commute to test concepts and prototypes and to process
field research. Through interviews with my candidates I found two ideal places to test
my bike. They are the campus of Rochester Institute of Technology and the Rochester
Public Market.

These two scenarios are selected based on four criteria: 1) Each is located in
Rochester so I can actually visit and do onsite research; 2) The full route I designed
for commuting is under two miles, an ideal distance for a short distance commuting
environment; 3) Each of the scenarios includes different types of road conditions
including several uphill and downhill segments; and 4) I witnessed many people in
these two locations carrying lots of cargo including backpacks, luggage, groceries,
etc.
RIT campus

“Founded in 1829, Rochester Institute of Technology is a privately endowed, coeducational university with nine colleges emphasizing career education and experiential learning... The RIT student body consists of approximately 15,000 undergraduates and 2,900 graduate students. Enrolled students represent all 50 states and more than 100 countries” (http://www.rit.edu/overview/rit-in-brief, 2014)

The route starts from a parking lot on north side of campus and it ends at Gordon Field House and Activities Center. Following this path, visitors can pass most of the iconic buildings of RIT and experience several uphill roads and downhill roads.
Rochester Public Market

Since 1905, Rochester’s Public Market has served the local community. It is open Tuesday, Thursday and Saturday all year. Ethnic delicacies, specialty items and local produce are all available there through local vendors. Local businesses surround the Market District.

The Public Market is near the northeast quadrant of Rochester, at 280 N. Union St., approximately three blocks north of E. Main St. Carpooling, public transportation, walking and cycling to the market is encouraged by its staff (http://www.cityofrochester.gov/article.aspx?id=8589936780).
Concepts and Possible Solutions

Rear-steering Bicycle/ Tricycle Concept

Design Process

The first concept I developed is called the “rear-steering bike concept.” Instead of connecting all functional gears with chain and lubricant, I chose to install the pedal directly on the hub of the rear wheel much like the construction of a unicycle wheel. In this way, the user doesn’t need to worry about rusting chain or gears. Additionally, with a large cargo carrier installed in the front of the bike supported by two 5-inch wheels on the bottom, the user is able to carry much more cargo when they are shopping at a place like the Rochester Public Market, Wal-Mart, etc. A banana saddle
is installed instead of a regular saddle for a better user experience so that people can shift their center of gravity to a more up-front position when the front carrier is not loaded.

I was excited about this idea and I wanted to test it by building a 1:1 mock-up with a fully functional steering mechanism and pedals. Professor Jon Schull suggested I visit Rochester Community Bike in Rochester, New York, where people donate bikes. There were also many bike mechanics there who were willing to help me.

Jim Robinson is a senior mechanic currently volunteering at Rochester Community Bike. Jim was very interested in my project and he gave me lots of bicycle parts as well as tips on how to organize these parts and make a mock-up quickly to test my ideas. He also suggested I take a welding class at Rochester Arc & Flame Center to learn MIG Welding techniques, which were critical for me to test prototypes in a real-life environment. Below is the very first mock-up I did for this concept.

I built this bike by flipping a child’s tricycle 180 degrees and cutting the front steering bar off. I installed a structure upon the rear wheel that allowed me to test pedaling. I
also extended the front wheels further to get more space in order for an adult to be able to use it.

Although this mock-up is not completely functional because of the enormous friction between the rear wheel and center hub, I learned many things from it.

**Flaws and What I Learned from Them**

Inefficient Pedaling: Because the rear wheel is a steering point that can’t be fixed on the frame, the motion of pedaling causes a series of unnecessary and disturbing movements to the rear wheel such as swaying, shaking and over-turning. Additionally, the muscles of both thighs need to hold the saddle in a relatively fixed position for an efficient pedaling experience. The energy transfers from muscles to wheel are inefficient because a huge portion of the energy is lost in the process of constantly struggling with steering and balancing. The pain caused by pedaling generally got worse and worse.

Discomfort: Because the rear wheel is not fixed, both of the thighs and bottom will experience great pain after riding a short distance. Additionally, back muscles and
waist muscles provide most of the power for steering instead of the muscles from the arm and shoulder. The muscles of the waist feel pain and soreness after pedaling a few times.

Confusing Steering: the steering of the rear wheel has to be the opposite way as the direction you are heading, which is confusing for most people and thus becomes a safety issue when turning a corner.

I learned several things from my first try. I decided to learn welding to help me build a more solid frame to test my ideas practically. The rear-steering mechanism is interesting but extremely hard to pursue due to many reasons that I stated before. The unicycle wheel powering concept surprisingly got lots of attention from the department but I had to find a perfectly sized unicycle wheel to test the possibility of a “chain-less” concept.

**Front Steering Bike/Tricycle Concepts**

**Design Process**

I started to work on my second concept soon after I started taking welding classes at the Rochester Arc & Flame Center. I learned lots of techniques including how to weld two steel tubes together permanently, which gave me more freedom to test my ideas.
I also successfully found a supplier online that sells fourteen- to sixteen-inch unicycle wheels for larger tricycles. I contacted them and bought a sixteen-inch unicycle wheel with two crank arms. The hub they installed in the wheel is a free wheel and single gear that perfectly fit my project.

At the same time, I came up with a new front steering concept that I felt strongly about. For a period of time, I was stuck with drawing lots of sketches and concepts to explore the shape of the frame. Professor Stan Rickel encouraged me to get back to mock-ups since I didn’t have a clear vision of how this concept worked. At that time, I started to realize that exploring the appearance of the bicycle was unhelpful because of the fact that through two hundred years of bicycle development, the designs we have today are already very advanced.

That was where I started to think differently. What really matters to me is to figure
out the user experience of riding a bike and how the user loads and unloads cargo with this new concept. In this way, I suddenly realized the answer is around the corner. I suggested installing a front cargo carrier that joins permanently on the frame, which is also beneficial for balancing and steering. In this way, a user can balance his center of gravity according to the weight of the cargo and the bike may not lift too far off the ground. Additionally, a user does not need to be concerned about steering because the weight of the cargo falls on the frame instead of the steering bar.

I started to mock-up my concept by collecting parts I got from Jim Robinson. I wanted to feel the steering and the paddling in case I needed back-up plans. Below is the second mock-up I did for testing.

It worked much better than the first mock-up and I did a 1:1 scale sketch on the
board soon after the mock-up. It turns out a sixteen-inch unicycle wheel works perfectly for this mock-up. The cargo rack in this design is twenty-four inches long and eighteen inches wide. I can shift my center of gravity front to back to adjust my position depending on the weight of the cargo.

According to my 1:1 sketches, I cut the steel tubes into small parts in different lengths and spent a week welding the frame. The result turned out to be acceptable. I assembled all the parts including two pedals, one saddle, front and rear wheels and the front cargo carrier.
Overall, this version worked much better than the last version after a few days of adjusting the mechanism. This bike can carry more than fifty pounds of cargo in the front carrier but is still fully functional. I did find problems with this design generated by the design of the cargo rack, including issues with ergonomics as reported by users. Many assembly details needed to be changed, polished, organized and redesigned.

**Flaws and What I Learned**

Overall design: With a load of cargo weighing around fifty pounds, I didn’t need to pay attention to control the center of gravity to prevent the front wheel from lifting up off the ground. It worked very well this way. But when the cargo is unloaded, I had
to shift my center of gravity to a more front-up position to keep the center of gravity around the center of the bike in order to prevent the front wheel from lifting off the ground. Additionally, a front-up riding position caused a lot of pain because of the discomfort of the saddle.

Steering bar: The steering experience is very comfortable for my height. But I felt too much pressure on my shoulder, which caused pain in my back, arm and shoulder. The width of the bar is also too short for stable controlling.

Saddle: The saddle needs a lot of work. My committee members liked the fact that it is longer than the other typical saddles for multiple riding positions but the overall shape of the saddle needs further consideration. The saddle has to be comfortable enough for a relatively longer riding experience.

Cargo carrier: It is a good idea to weld the cargo carrier on the frame instead of the front fork. But this design creates an illusion that makes the user feel that the bike still goes straight even if he/she steers the bike frequently.

Other Possible Solution: Tricycle Concept Exploration

I also tried a tricycle version after the mock-up was completed. I installed two 15-inch wheels in the front and connected them with metal bars for a more stable
riding experience. This solution gives the user more space and time to utilize steering function without worry about controlling the balance and weight. A tricycle version doesn’t solve all of the problems such as flipping off and discomfort but it does provide a more relaxed riding experience and allows the user to load much heavier cargo. The steering mechanism could be tricky to design but it is possible.

The overall scale of the tricycle concept is dramatically larger than the bicycle concepts. Because of the complicated steering mechanism, the weight goes much higher and the risk of getting rust increases too.
Final Solution

Design Process

The front steering concept became stronger over time because of its great potential and the simplicity of the design. The mechanism of this concept is also very simple and robust. The solid build of the crank and the completely sealed hub are unbreakable and resist rust. Additionally, the second concept is a relatively smaller package compared to the bicycles currently on the market, which makes it easier for users to store in small spaces such as inside a car or in a closet.

During the development of this concept, I mainly focused on how to make this bicycle more stable, more comfortable to ride and easier to load. The first thing that came to my mind was to test the ergonomics. For a more realistic experience, I bought a second-hand stationary bicycle for testing and used myself and several friends as testers. Below is the stationary bike I was using for the test. The height of the saddle and steering bar is adjustable, which means the distance between pedals and saddle is adjustable too. The scale of the banana seat is large enough for testing.
With a few days of ergonomics testing, I got good data for designing the dimensions of a better frame. Besides the wood board on top of the saddle, I also tried different types of sponges on top of the base to understand the riding positions in different conditions and the best material for a comfortable user experience. Additionally, all of the components can be customized with different materials and types that I collected. This is one of the dimension groups that perfectly fit for a 5’9” adult. Here is the data for this group:

The distance from grip to saddle is 25 inches to 27 inches. The forward leaning angle between saddle and grip is 3 degrees to 15 degrees (this number could be different depending on position of the sitting spot). The compression of saddle is 1 inch to 2 inches depends on the materials. The length of saddle could be 15 inches to 24 inches long, and 4 inches to 5.5 inches wide. The distance between saddle and hub is
24 inches and 25 inches.

For the welding process, I chose to use a one-inch diameter round steel pipe instead of a 1.5-inch square steel pipe, which is a universal dimension for most of the bicycles in the market. According to my ergonomics study, all dimensions for welding were changed including the overall length, the length of the steering bar, the height of the fork and the saddle, etc.

The welding of round tubes is much more complicated compared to using square ones. Round tubing is difficult to cut without the help of special frame welding tools. All of the welding joints had to be sanded and polished for a better quality of powder coating process later.

Here is the process of welding:
Soon after I successfully built the main body, I started to collect bicycle parts fitting this particular bicycle such as the front fork, head set, paddles, chain stays, etc. There was a lot of drilling required on the tube in order to fix the parts together with screws and bolts. After all of the parts and components were in place, I started to pre-assemble the parts to test the construction.
The headset installation for this handmade bicycle is one of the most challenging assembly processes. A full set of headset components has more than ten parts such as cap bolt, compression ring, two cartridge bearings, seal, upper and lower head-tube races, etc. All of the parts have to be perfectly fitted and function well with each other. This bicycle’s headset has an extremely low steering position because of the unique frame appearance. Most of the cap bolts in the market are either too short or too fragile for this bicycle to achieve a fully functional and robust steering experience. I built the cap bolt myself by cutting a steel bolt in half and connected these two parts with a twenty-inch steel rod.
The assembly process took a week, which is much longer than I expected. Many of the parts I found were either not a perfect fit with each other or were too fragile after being welded to the body permanently. What follows are the details of the parts that were changed and customized. There were still problems that needed to be solved and I learned many things from the process.

I decided to design the banana saddle from scratch because I couldn’t find a perfect one with the right dimension from a local store. I shaped and carved the saddle base with ash and wrapped two pieces of 2x4-foot blue sponge inside with a piece of white leather. I carved two channels on the bottom of the wood base for installation of supporting bars. Both of the bars are clearly bent after many test rides because
the material I chose was steel rod, which can be bent very easily. Aluminum would work better than steel for this particular component.

The rear-wheel bearing is another customized component that failed twice during the assembly process. The original idea is to join a universal bearing made of cast iron to the seat stays. It broke twice during the test ride because of the fragile quality of the bearing, which had been heated and cooled many times in the previous welding process. My way of solving this problem is to completely cut the bearing off the seat stays and to re-join a new set of bearings made of solid steel instead of cast iron.

To make a bearing from scratch, my design is to cut a short piece of steel tube in half
and weld one of them permanently on the end of the seat stays and tighten them with screws and bolts.

A wheelie bar is a rod cage that extends from the back of a vehicle and is connected to wheels that help keep a car from flipping backwards during sudden acceleration. A customized wheelie bar may help this version of design from flipping backwards. The installation process is quite straightforward. Like most wheelie bars, I designed a triangle construction fixed on each end of the seat stays. Neither of the connections is permanent in case users want to take it off for cleaning or customizing.
The cargo carrier is still installed in the front with a bicycle saddle post-clamp lock and it can be removed depending on the scenario. It is joined directly to the head tube.
This bicycle is designed to be functional for both of the situations below. Firstly, people are able to transport cargo or goods in a short-distance commuting situation. Additionally, people can enjoy riding this bicycle without cargo and they can even easily remove the cargo carrier.

**Flaws and What I Learned**

Flipping backward problem:

This bicycle still flips backward sometimes when experiencing sudden acceleration due to a relatively backward saddle position. The installation of a wheelie bar plays a critical role when there is the threat of the bike flipping backward. The wheelie bar immediately stops the bike from flipping backward and helps the front wheel fall back to the ground, but it doesn’t solve every problem. Sometimes designs can
create new problems when successfully solving existing problems.

Discomfort of Saddle:

The banana saddle causes lots of pain on the inside of the thighs because of the width and the material. There are many kinds of materials that are acceptable for creating a comfortable sitting experience. I need to explore more materials and try different sizes.

Cargo Carrier:

The cargo carrier is an extended part of the bike frame that can be visually confusing when a user steers the bike. It creates an illusion that may lead users to feel that the bike is going straightforward instead of turning left or right when they steer the front fork. I never realized that this could be a problem until I took had friends take test rides. Almost all of the testers find it uncomfortable.
Conclusion

Bicycle design is one of the most challenging projects in the Industrial Design field. I spent a couple of weeks studying the history of the bicycle just to get familiar with every kind of bicycle/tricycle ever made. I also paid several visits to local bike stores and Rochester Community Bike to find bicycle mechanics willing to help me understand the construction of the bicycle. The final concept solved most of the problems I addressed in “The Problems” section. The bicycle is designed and built solidly without gears and chain. The 3-speed hub installation for the rear wheel contains the gear-shifting system inside of the hub. It is very robust and strong for surviving all weather conditions. The banana saddle gives the freedom of shifting the
center of gravity during riding, providing a better user experience. This bicycle can carry large and heavy cargo for scenarios such as public market shopping or campus commuting. The wheelie bar design prevents the bike from flipping off the ground. The overall bicycle is a relatively small package that can be fit in an SUV or a sedan.

But there are still many problems in the design that need to be studied and solved in the future. The banana saddle is not comfortable for longer distance riding experiences. The center of gravity of the rider needs to be adjusted all the time for balancing the bicycle. The wheelie bar doesn’t solve everything because the front wheel still flips off the ground.

The final design is a good exploration of a solidly built cargo bicycle and a research-based attempt at creating a unique riding experience for people. I’m always looking for more opportunities and ideas in this area for future research and design projects.

**References**


Bike to Basics: A Cargo Bicycle Design for Short Distance Commuting

BY CONG YAO


