Dr. Andrew Rawicz
School of Engineering Science

Simon Fraser University
8888 University Drive
Burnaby, BC
V5A 1S6

Re: ENSC 440 Proposal for a virtual reality bicycle trainer

Dear Dr. Rawicz:

Enclosed is a proposal for our virtual reality bicycle trainer. Our proposed product is an attempt at allowing amateur and professional cyclists practice indoors in a stimulating and realistic environment, so that they can train during the off season.

This proposal is designed to give you an overview of our proposed product. We discuss our motivation, budget, team members, time schedule and the trainer itself. Our document also discusses the scope of this project, and future explorations along similar lines.

Our team is composed of 4 senior engineering students from the systems, electronics and biomedical options, bringing complementary views to the project. If you have questions regarding our system, please contact us at ensc440-v-cycle@sfu.ca and we will help to resolve your issue.

Regards,

Dan Edmond   Mike Henrey   Jack Qiao   Lukas-Karim Merhi
The V-Cycle Team

Enclosure: *Proposal for a Virtual Reality Bicycle Trainer, the V-cycle Pro*

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cycle

Project Proposal

Executive summary

Indoor bicycle training is difficult to make fun and engaging, but may be the only option for the avid cyclist during the winter, or someone using cycling as a rehabilitation tool after knee injuries. Current indoor trainers don't provide a realistic riding experience. Most do not allow the user to ride their own bike, and those that do fail to provide an experience that's engaging enough to maintain the user's interest. The *V-cycle Pro* by V-cycle aims to address these issues with the indoor bike trainer by allowing the user to cycle their own bicycle in one of our virtual custom terrain maps or anywhere in the world through our Google earth interface.

The device itself will consist of a frame to support any bike size, and will use real-time elevation data to control the angle of the bike and the pedaling resistance. These features, coupled with speed and rotation sensors and an LCD display for visual feedback of our terrain or of Google earth images will provide an experience that is dynamic and exciting for users. Imagine being able to climb up steep hills and rush down the other side, or pedal through the streets of Paris to look for the best restaurants.

Development of the V-cycle is budgeted at $1100. This is a conservative yet reasonable estimate given the expensive structural and mechanical components required for the design. Funds have already been sourced from the Engineering Student Society Endowment Fund, and we plan to retroactively apply for funding from the Wighton Fund after the product demo. The remainder will be funded by team members.

Our team brings a wide range of technical experience and backgrounds together. Interest and experience in mechanical systems, hardware design, computer software, cycling, and biomedical devices converge to make an effective team with the drive to see this product through to its completion. Administrative and technical roles and responsibilities detailed in this document aim to leverage our strengths and personalities, and goals for growth within the conceptualization of the v-cycle. Responsibilities have been clearly defined so that the team is accountable to one another.

We plan to map our progress careful with anticipated milestones to stay on schedule, and will discuss roadblocks at weekly meeting to determine the impact on integration timeline. V-cycle is confident in the ability of its team members to deliver on their administrative and technical responsibilities in a timely manner, and show the world the next generation of indoor bicycle training.

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1. Introduction

Bicycle training in the off-season is a difficult task. In the Canadian environment, wind, rain and cold make cycling outdoors in the winter unpleasant and often dangerous. However many cyclists endeavor to stay fit during these colder months: professionals wish stay in top form for spring triathlons, and amateurs desire engaging exercise to stay in shape. Providing a means for amateur and professionals alike to enjoy the sport of cycling in a realistic and safe environment year round is the goal of our project.

Currently a few devices attempt at addressing these needs. Many gyms and even homeowners have stationary bicycles that provide resistance and allow the user to select primitive 'courses' to strengthen and exercise different leg muscles. Variable resistance trainers are devices that allow the user to operate their own bike indoors, and provide a realistic resistance profile – the resistance varies proportionally or exponentially with the speed. Rollers allow the exerciser to practice balance at the same time as exercising their leg muscles; these devices allow for multiple degrees of freedom and the bicycle can even "tip over". None of the products, however, are capable of keeping a rider engaged throughout the entire Canadian winter.

The objectives for our product are numerous. We wish to provide a lightweight trainer for use with the owner's cycle. This trainer must provide proper force feedback based on the speed of the cycle. In addition, the trainer will provide a visual display capable of keeping the user entertained. The display will interface with Google Street View or a terrain generating system so the user will see objects local to their virtual position. In addition, the terrain data will dictate the angle at which the user is riding at, and the bike itself will tilt to reflect this angle. Finally the resistance will vary appropriately based on this same terrain data: when the user is riding uphill the resistance will increase, and when facing downhill the resistance will decrease.

When compared with current systems, advantages of our device can be seen. Current systems that provide visual stimulus to the user either do so in a 'primitive' manner such as showing the current slope of the presumed path, or incorporate virtual racetracks or other paths for the user to ride along. Our system will allow the user to visit the Leaning Tower of Pisa in one trip, and downtown Berlin the next. There are so many interesting places to see in our world, and an interface with software like Google Street View will provide these to the user. The realistic environment of our system, from the changing bike angle to visual and force feedback make our device much more enticing to both amateur and professional users than other products.

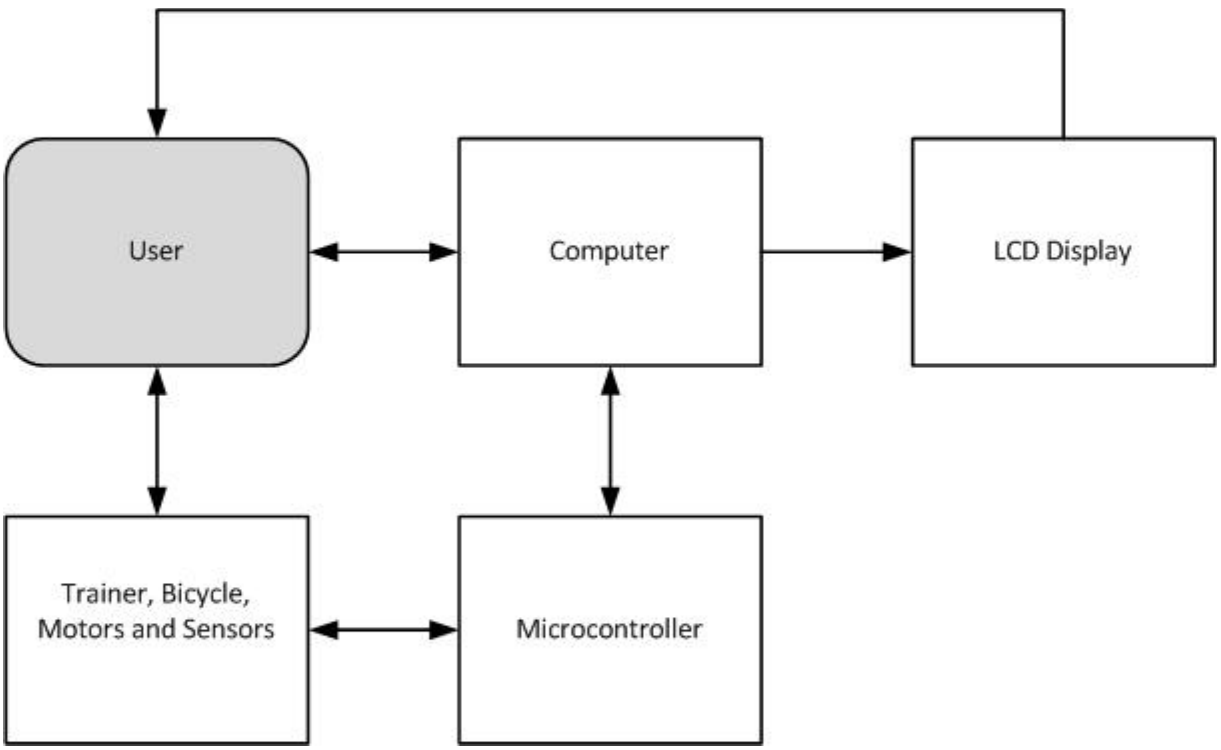
In the following pages, we outline our system in more detail. First we discuss the product itself, and give some implementation details. Following is a proposed budget, and funding plans. This is followed by our design and prototype schedule, and a description of our team. Together, these sections indicate how we plan to build and test a device over the next 3 months, and how we intend to build and retain a strong team in the process.

2. Our System

System overview

Our system is composed of a few major subsystems. The user is a key component of our design, and usability is considered a high priority in our system. The user provides input to the system through the computer interface (selecting their cycling route), pedaling and turning the bicycle handles to control their path. Our system monitors this input and provides feedback to the user through resistance to pedaling, and visual stimulus on the LCD screen.

Figure 1: System Overview



The first step for the user is placing their bicycle into the trainer, which is easily completed by one person. Then they can select a course to cycle on the computer. This may be either in Google Street View, or a 3d generated track from our library. After they mount the bike and start pedaling, the microcontroller starts reading sensor input including velocity and turning information, and gets terrain information from the computer, and provides the appropriate feedback to the computer and the user. Through the use of motors, the resistance is varied appropriately and the bike is raised or lowered to give the user the feel of riding up or down hills. The velocity information is also provided to the computer.

The computer is responsible for powering the graphics display information to the user, and the terrain information to the microcontroller. The display is updated as the user progresses through their route, and the terrain information is used by the microcontroller to provide force feedback to the user. The LCD screen is the method of providing visual feedback to the user.

Existing Solutions

Current devices that attempt to provide training systems for riders in the off season generally have some but not all of the characteristics of our proposed device. Our system incorporates both visual and force feedback, and keeps the user engaged with a virtual reality display.

Stationary bicycles

This type of exercise equipment allows the user to perform bicycle riding motions indoors, however suffers from a few limitations. The stationary bicycles are generally not very ergonomic, and many athletes would prefer to use their own bicycle, with the correct setup and feel. In addition, with a stationary bicycle one does not feel like they are on the road or path, it is not a natural feel. In their defense, stationary bicycles occasionally have built in visual feedback including racing simulations which can engage the user for longer periods of time.

Variable resistance trainers

Variable resistance trainers allow the user to use their own bicycle in a device that simulates wind resistance. The resistance profile is often quite close to what a rider would feel riding on a level surface like a flat highway. However, these devices offer no method of simulating hills and can be quite loud when used. The rider's experience with a resistance trainer is only realistic to a small extent.

Rollers

Rollers can be used to allow the user to train in the off season. These consist of a frame with 3 roller bars – 2 under the rear wheel and one under the front. The user must balance while riding and the feel can be quite unnatural; the user is often told to practice in the doorway to avoid falling at first. This system has the unique advantage of allowing the user to build balance and stabilizing muscles while riding indoors.

Research and Design Methods

In order to construct our prototype, a number of steps must be taken. We are currently in the research and design stage, and have been solidifying our plans and making parts lists.

Creative design work

Our design methodology was quite liberal and creative. We had a couple brainstorming sessions to outline our constraints and design requirements. Then we all went away and formed creative solutions to each problem we could find. Finally we brought all of our ideas together, and selected the best solutions to form our final design.

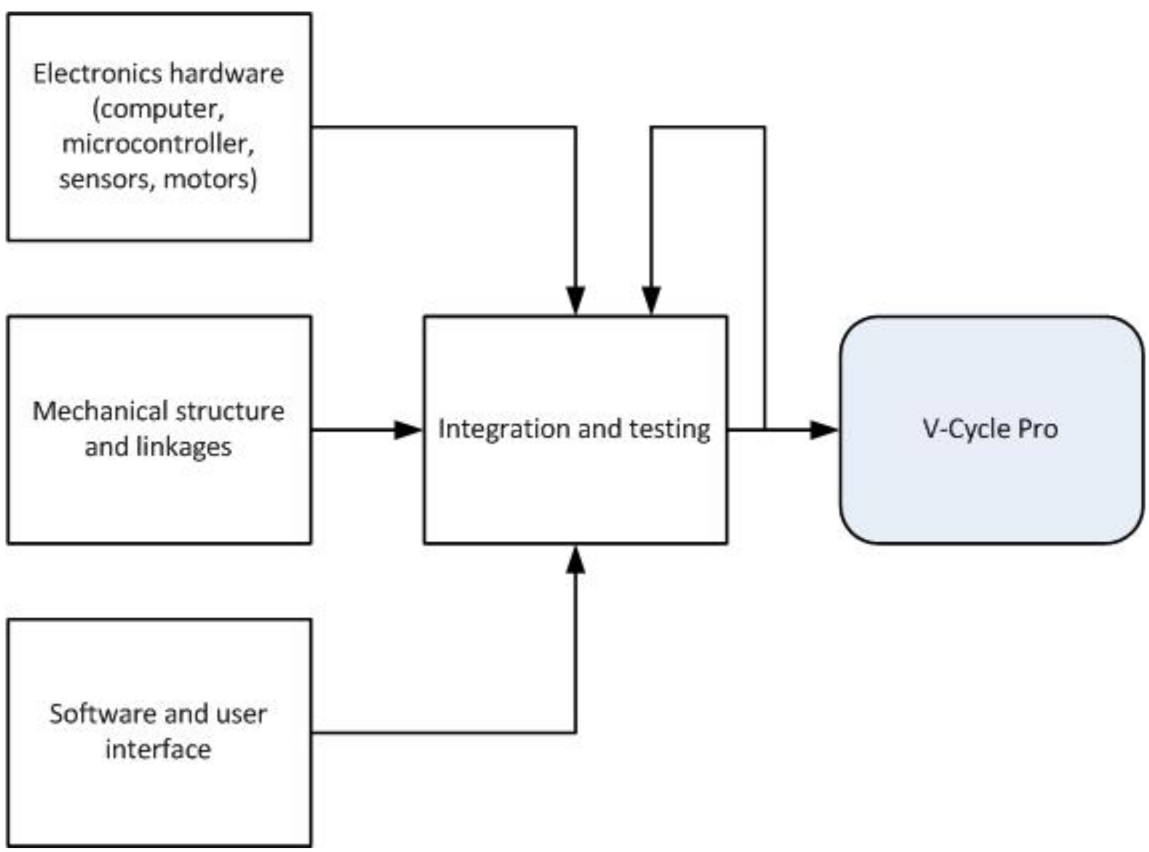
Designing the prototype

Writing the formal specifications and selecting parts has been a more restrictive process, and is the stage we are in now. We are currently taking our creative solutions, and making them practical by finding suitable parts and designs.

Testing and implementation plan

Because our project draws from multiple disciplines and contains many subsystems, we predict testing and implementation will be a major task. We will have weekly milestones for each system, with testable requirements. This means that each system will be individually functional throughout the course of the project. Formal implementation will begin about a month before the demonstration date. This allows us time for multiple iterations of implementation and testing before we demonstrate the final product, as seen in the following conceptual diagram.

Figure 2: Testing and integration plan



3. Budget

A tentative budget for the project follows. Note that each item is given a range of costs, allowing us to gauge the upper and lower limits of possible total costs. All components to be shipped are estimated to have shipping and duty of $20 per item.

	High	Low
Structural support (including raw materials, custom milling, possibly welding costs)	$100	$20[1]
Linear motion system	$60	$10[2]
Linear drive system (screw, belt, or possibly rack and pinion)	$60	$40
Used bike trainer	$150	$100
High torque motor	$140	$140
Motor drivers	$160	$140
Arduino microcontroller board	$100	$0[3]
LCD screen	$75	$75
Miscellaneous mechanical parts	$120	$120
Miscellaneous electrical parts	$130	$130
Total	**$1095**	**$775**

[1] High represents using a metal frame and low represents a wood or MDF frame
[2] High represents an off-the shelf linear motion system, and low represents a DIY skate bearing design
[3] An Arduino microprocessor may be acquired from a previous project at no charge

To err on the side of caution, we will use the figure of $1100 as our total budget.

Sources of Funding

We have sought funding from the ESSEF, and due to possible biomedical applications may receive some money from the Wighton Fund after the completion of the project. The amount not covered by these sources will have to be supplied by members of the group.

Due to the high cost of our project, we are considering adding further biomedical applications (i.e. more of a stability exercise component) in order to more easily acquire funding.

4. Time schedule

Figure 3 is the Gantt chart that shows the allocated time for the numerous tasks involved with our project. Figure 4 outlines the completion dates for the tasks mentioned in the Gantt chart.

Figure 3: Gantt chart

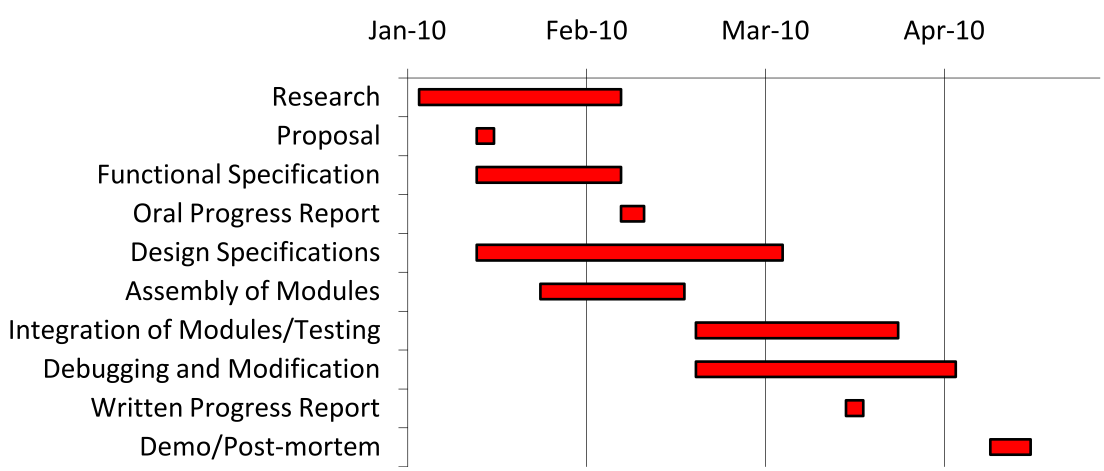
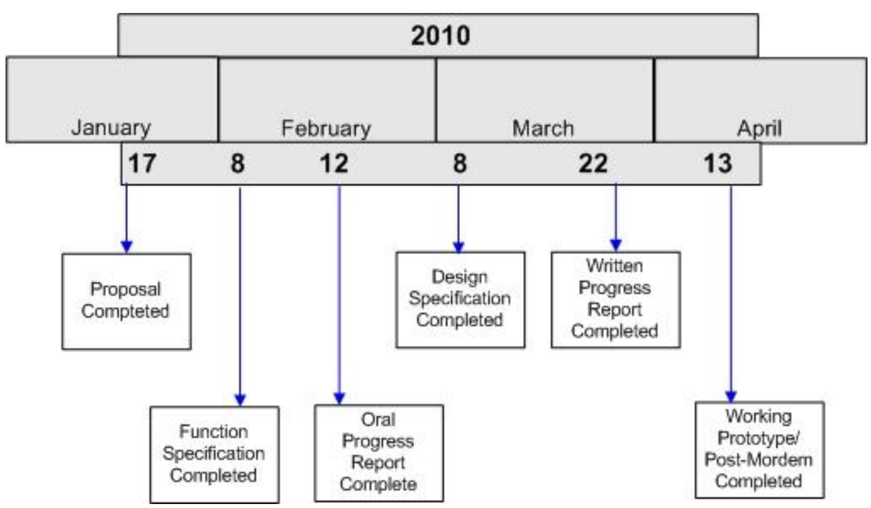


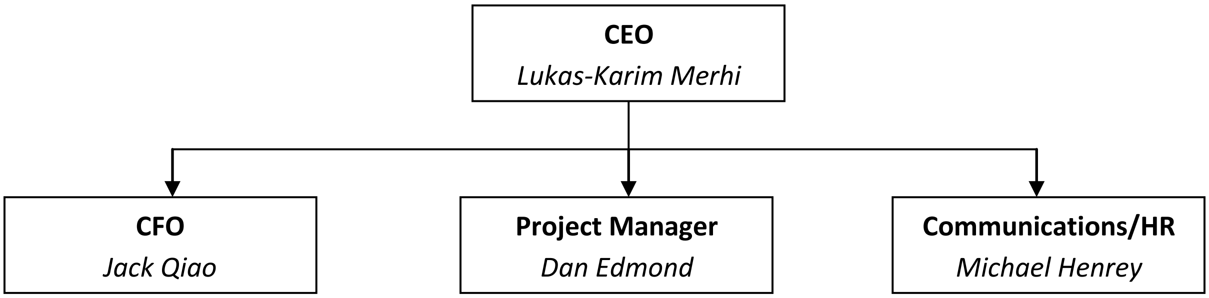
Figure 4: Milestone Chart



5. Description of team

Structure

Figure 5: Organizational Structure



While our team will be working closely together on many aspects of the design work, we identified the need for strong leadership and clearly defined roles and responsibilities. Organizational roles were defined in addition to our technical roles detailed in *"Design Philosophy"*. The organizational structure of our team is shown in Figure 5.

CEO (Lukas)

Responsible for maintaining a customer-driven perspective throughout the entire design process, ensuring the timely delivery of project milestones, and understanding the time line required for smooth, incremental integration of the entire system.

Lukas-Karim Merhi is in his last year of studying Biomedical Engineering at SFU. His technical and business management experience has been tested and proven through work experience in store project management and IT network management at Glentel Inc. In his role as CEO, Lukas draws upon leadership and mediation skills from volunteering with EWB at SFU by organizing Vancouver biggest international development conference, Bridging the Gap 2009.

Communications and HR (Mike)

Responsible for enforcing proper use of group email policies, ensuring consistency in documentation and external communications, and having fun.

Mike Henrey is in his final semester of studying systems engineering at SFU. His technical experience has been tested and proven through work experience in safety systems at TRIUMF and new product development and prototyping at Technology Brewing. In his role as Communications and HR manager, Mike draws upon skills from his time volunteering with EWB in Zambia, bringing people skills, communications experience and the ability to resolve problems with little support in less-than-ideal situations.

CFO (Jack)

Responsible for tracking expenses with our budget, identifying additional sources of funding, and sourcing used/refurbished parts to reduce BOM cost where possible.

A 5th year Systems Engineering student, Jack excels in the visual arts, 3d programming, as well as mechanical design and CAD/CAM. His multi-disciplinary approach to systems integration will be a valuable asset throughout the course of the project.

Product Manager (Dan)

Responsible for understanding all technical aspects of subsystems and how they connect, ensure that all independent subsystem are designed for seamless integration, and performing audits of all subsystem designs.

Dan is a 5th year electronics engineering student at SFU with an interest in computer hardware, and has demonstrated his aptitude in electronics hardware and VLSI design at Research in Motion, Broadcom, and PMC-Sierra. Being an avid cyclist himself, Dan brings an extensive knowledge of bicycle mechanics and a passion to see the product through to its greatest potential.

Meetings

Meetings will take place twice weekly. The focus of Tuesday meetings from 2:30-4:30 will be technical in nature, and will provide an opportunity for group members to update on the progress made with sub-systems. It is intended that this time be used effectively to pool the collective resources of the team and cite issues with integration before they arise. Saturday meetings from 12:30-1:30 will be used primarily as organizational meetings where we will review weekly milestone deliverables and revise if necessary, address administrative issues, and discuss team dynamics. Team members will rotate the responsibility of taking minutes during meetings.

Design Philosophy

Subsystems will be designed and tested by each of our team members. Subsystem allocation is done based on the strengths and interests of team members. Preliminary allocation is as follows:

MCU Interfacing Sensors, Motors, computer and MCU Programming – Dan and Lukas
Mechanical Structural and Mechanical Design – Mike, Jack
Computer Software – Jack

Subsystems design and testing before integration is the responsibility of those allocated to it. The product manager will audit paper designs and test plans to facilitate the road map. It is expected that design of subsystems will carefully consider the requirements of connected systems, and that any software will be written such that system parameters are easily modified during the integration phase. As mentioned previously in this proposal, a schedule of weekly milestone deliverables for each subsystem will be adhered to in order to allow for sufficient integration time.

Conclusion

Cycling has become the fastest-growing type of transportation in the city of Vancouver. It supports a clean, green and healthy mode of transportation that can be an everyday choice for commuters [1]. With that in mind, we are all aware of the weather challenges to cyclists in this city or even all over Canada; therefore we here at V-Cycle are committed to providing cyclists, professionals and amateurs alike, with a means to enjoy the sport of cycling in a realistic and safe environment year round.

In addition, our product can act as a knee rehabilitative assistive device. Cycling is commonly used for rehabilitation after knee injury, surgery, or as part of the management of chronic degenerative conditions such as osteoarthritis [2]. This product will enable patients to pursue their rehabilitative program from home in an engaging and interactive way.

Our proposed home exercise module enables customers to use their own bikes and stay fit by enjoying a 3D terrain that simulates elevation terrain and increased resistance, and handlebar turning capabilities. The use of your own bike will not only translate to a more satisfying workout for our customers, it will also reduce the space and materials required compared to dedicated indoor bikes, making our system more cost effective and environmentally sustained than competing systems.

The proposal outlines our system overview, existing systems, research and design philosophy, budget, time schedule, and finally a description of our team and how it is organized. The Gantt and milestone charts in the schedule section show that this project will be completed in due time.

References

[1] **"Cycling in Vancouver," City of Vancouver, 2009. [website]. Available: http://vancouver.ca/engsvcs/transport/cycling/. [January 18, 2010].**

[2] **"Cycling for Knee Rehabilitation," Cartilage Health, 2009. [website]. Available: http://www.cartilagehealth.com/cycling.html. [January 18, 2010].**