WHEELCHAIR DESIGN IN DEVELOPING COUNTRIES

http://web.mit.edu/sp.784/www

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COURSE INFO

Lecturers: Amos Winter, PhD Candidate, Mechanical Engineering
Amy Smith, Senior Lecturer, Mechanical Engineering

Units: 2-2-5 (Lecture-Lab-Homework)

Lecture: Required, can miss two, but not more without instructor permission. Attendance taken starting second week of class.

Project and Labs: Project teams and class presentation times chosen next Thursday. Lab groups will choose own meeting time.

Homework: Project and team website primary components of homework. Additionally there will be readings and short assignments.

Grading: Final course grades will be assigned A-F.

- Class participation/homework: 10
- Strategy presentation: 15
- Concept presentation: 15
- Most Critical Module (MCM) Presentation: 15
- Final presentation and prototype: 25
- Team website: 20

Course website: http://web.mit.edu/sp.784/www/index.html
For a full description of the class, see “detailed course info” on the website

PROJECT

Team: 3 to 5 members with lab instructor

Collaboration: Partnership between MIT students, US and European experts, and wheelchair manufacturers

Deliverables:

- PowerPoint presentation for the Strategy, Concept, MCM, and Final prototype.
- Poster for The Museum of Science in Boston in May
- Prototypes: Physical solution to each teams' MCM for MCM presentation. Proof-of-concept prototype for final presentation
- Website chronicling project development. Pages dedicated to major milestones. Website completed by summer fellows

RESOURCES

Monetary: $4000 for prototyping

Manufacturing:

The Edgerton Center Student Shop

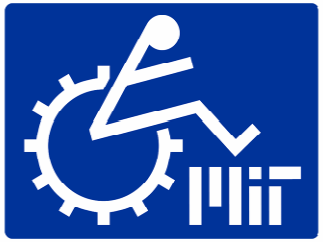
THE HOBBY SHOP

Parts: African wheelchairs and bicycle components

Lab Space: Project work and storage in 1-005

FELLOWSHIPS

- At least 7 available
- Bring WDDC technology back to partner workshops
- Work in any or all 13 partner shops
- ~10 weeks
- Apply through PSC Fellowship process



SYLLABUS

Week #	Tuesday	Thursday	Assignments	Milestones
1 (2/3)	Introduction to wheelchairs in developing countries and review of potential projects	Wheelchair/Trike relay race around campus	Readings about wheelchair usage and distribution, Review projects	
2 (2/10)	2007 summer fellow presentations on last year's projects Alison Hynd speaking from the PSC about summer fellowships	Designing wheelchairs for the developing world and deterministic design process Choose project teams	Read 2.007 lecture notes on design process, define functional requirements of project, Reading from Nothing about us without us, watch videos of wheelchair workshops and PAWBA conference	
3 (2/17)	Wheelchair Biomechanics/Ergonomics and design for human use	Power output test up ramp in basement	Power calculations from class activity, reading from Positioning a Wheelchair, 3/1 - Encouraged to visit 2.007 lecture	
4 (2/24)	Abdullah and Daniel speaking to class	Abdullah and Daniel speaking to class	Reading from Independence through Mobility, 3/5-Encouraged to visit 2.007 lecture, 3/8-Encouraged to visit 2.007 lecture	Strategy presentations during lab period
5 (3/2)	Guest speaker: Amy Smith and Amy Banzaert Appropriate technology, idea to product, successfully inplementing technologies	Wheelchair role-play Results from Tanzanian Wheelchair Foundation Study	Readings about different appropriate and inappropriate technologies	
6 (3/9)	Guest Speaker: Joost Bonsen Developmental Entrepreneurship	Guest speaker: Sarah Bird Businesses and marketing in developing countries	Reading from HBS case study "Note on Marketing Strategy"	
7 (3/16)	Manufacturing processes and strategies Watch video from local workshops in Africa and Vietnam. Watch economies of scale presentation from PAWBA conference.	Manufacturing processes and strategies Watch video from local workshops in Africa and Vietnam.	Reading from Mastering the Machine	Concept presentations during lab period
8 (3/23)	Spring break	Spring break		
9 (3/30)	Material science/ mechanics of materials/welding with Mike Tarkanian and possibly Mary Boyce	Material science/ mechanics of materials/welding with Mike Tarkanian and possibly Mary Boyce	Reading from Mechanical principles of wheelchair design	
10 (4/6)	Guest Speaker: Prof. Dan Frey Product design process and design of prosthetic devices	Critique of different mobility aid designs Sketch exercise of new mobility designs and class rating	Project work	
11 (4/13)	Guest speaker: Ralf Hotchkiss Talking about his career and designing wheelchairs	Guest speaker: Ralf Hotchkiss Talking about his career and designing wheelchairs	Project work	Most critical module (MCM) presentations during lab period
12 (4/20)	Guest Speaker: Prof. David Gordon Wilson Human-powered machines	Guest Speaker: Rory McCarthy Handcycle design and racing	Reading on wheelchair user image	
13 (4/27)	Project work	Project work	Project work	
14 (5/4)	Project work	Project work	Project work	Poster for Museum of Science display on Sat, 5/10
15 (5/11)	Project work	Project work	Project work	Final presentation of project with a working prototype during lab period

February 5, 2008

MOTIVATION
World's disabled

- The World Bank and other authorities estimate that there are as many as **600 million persons with disabilities around the world**, making them one of the largest minority groups of unserved, marginalised people. (UNESCO Bangkok)
- About 600 million people in the world experience disabilities of various types. **80% of the world's disabled people live in low-income countries**; the majority of them are poor and do not have access to basic services including rehabilitation facilities. (World Health Organization)
- Between **20 and 50 million people globally are estimated to be injured or disabled in road traffic accidents each year**. (World Health Organization, 2004)
- Close to **ten million severely or moderately disabled people are added each year** to the total global figure – or about 25,000 every day. (Helander, 1999)
- **70% of disabled people in developing countries are estimated to live in rural areas** (Groce, 1999)

(Statistics provided by Motivation UK)

MOTIVATION
Need for wheelchairs

- The WHO and Pan American Health Organisation (PAHO), estimate that only **1-3% of people with disabilities in the South who require rehab services have access to them**. (Helander, 1999)
- Most people who sustain a **spinal cord injury in the South die within two years**, compared to a normal life expectancy in the North. (Werner, 1998)
- Conservative estimates put the number of people with disabilities in developing countries at close to half a billion. Of these, an **estimated 20 million require wheelchairs to be mobile**. (United States Agency for International Development, 2003)
- An estimated **95% of people who need a wheelchair don't have one**. (Werner, 1998)
- **Below 1% of the need for wheelchairs in Africa is being met through local production**. (United Nations Development Project, 2002)

(Statistics provided by Motivation UK)

MOTIVATION
Consequences due to lack of mobility

- **Disability is both a cause and a consequence of poverty**. Eliminating world poverty is unlikely to be achieved unless the rights and needs of people with disabilities is taken into account. (UK Department of International Development)
- In Tanzania, **households with disabled members are 20% more likely to be living in poverty**. (UK Department of International Development, 2005)
- "**98% of children with disabilities in developing countries do not attend school**." Earlier studies by UNESCAP and UNICEF show that this deplorable condition also applies to the Asia-Pacific region, where only around 2% of children with disabilities – one in every fifty children – have access to education of any sort. (UNESCO Bangkok)
- Worldwide, **only 2% of disabled children get any schooling**. (Action on Disability and Development, 2006)
- **Men, women and children who are discriminated against often end up excluded from society, the economy and political participation**. They are more likely to be poor. (UK Department of International Development, 2005)
- **Women and girls with disabilities face double discrimination based on disability and gender.** As a group, they fare far worse than nondisabled women or disabled men on most indicators of financial, educational and vocational success." (Mobility International USA, 2002)

(Statistics provided by Motivation UK)

ROLE OF MIT IN DEVELOPING WHEELHCAIR TECHNOLOGY
What MIT can offer

- Enthusiastic, creative students who are excellent engineers and work for FREE
- Resources, facilities, manpower to pursue high risk/high payoff projects that workshops or NGOs may not otherwise be able to develop
- A fresh perspective on wheelchair problems; new students ever year
- Opportunities for cross-cultural, collaborative exchange of ideas
- World-wide recognition of MIT draws attention to wheelchair issues

BETTER TECHNOLOGY THROUGH COLLABORATION

Goal: By partnering with expert organizations, MIT can aid in making great improvements to mobility technology in developing countries

Innovation

MIT

- Next generation of great technical minds
- Excellent facilities/resources
- Strength of MIT reputation
- Specialize in sound engineering and innovation
- Students work for free

Local knowledge

Example: Mobility Care

- Best understanding of community
- Working directly with wheelchair users
- Knowledge of local factors: parts/materials, labor skill, cultural stigmas, terrain

Experience

Example: Whirlwind

- 30+ years designing wheelchairs
- Experts in wheelchair requirements for developing countries
- World-wide workshop network

PERSONAL MOTIVATION TO IMPROVE WC TECHNOLOGY
Summer 2005: Assessment of WC technology in Tanzania

Supervision organizations

- Tanzanian Training Center for Orthopedic Technologists, Moshi, TZ
- Whirlwind Wheelchair International, San Francisco, USA

Interview locations

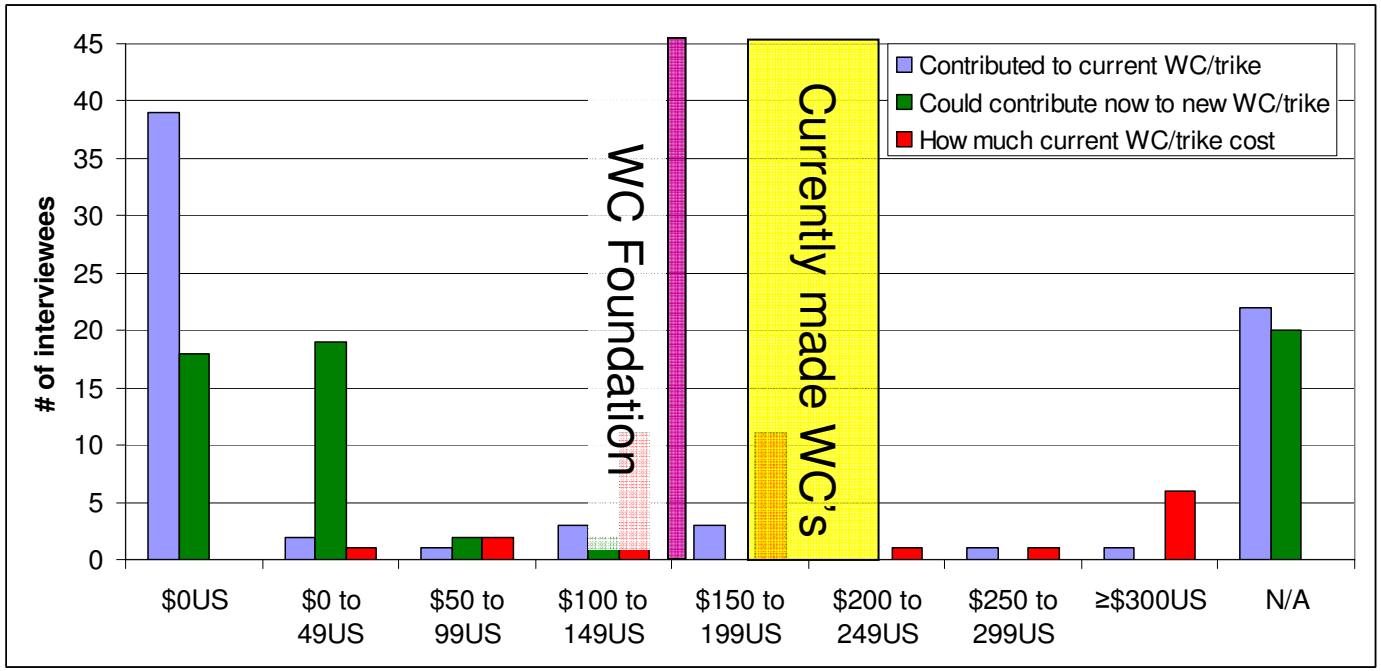
Parties interviewed

Wheelchair users

Wheelchair workshops

Wheelchair advocacy groups

TZ WHEELCHAIR ASSESSMENT
Opportunities for purchasing and competing with imports



- $100 to 150 price gap between what chairs cost and what people can afford
- Most people rely on donations to acquire a wheelchair

Largest donor in TZ

Wheelchair Foundation
"Serving the World"
hope
Circling the Globe with Friendship
mobility

- Since 2000, WC Foundation has donated nearly 7,000 WCs in Tanzania
- Each WC foundation chair costs $150US, $50 to $100 less than Tanzanian WCs but same price as TZ tricycles

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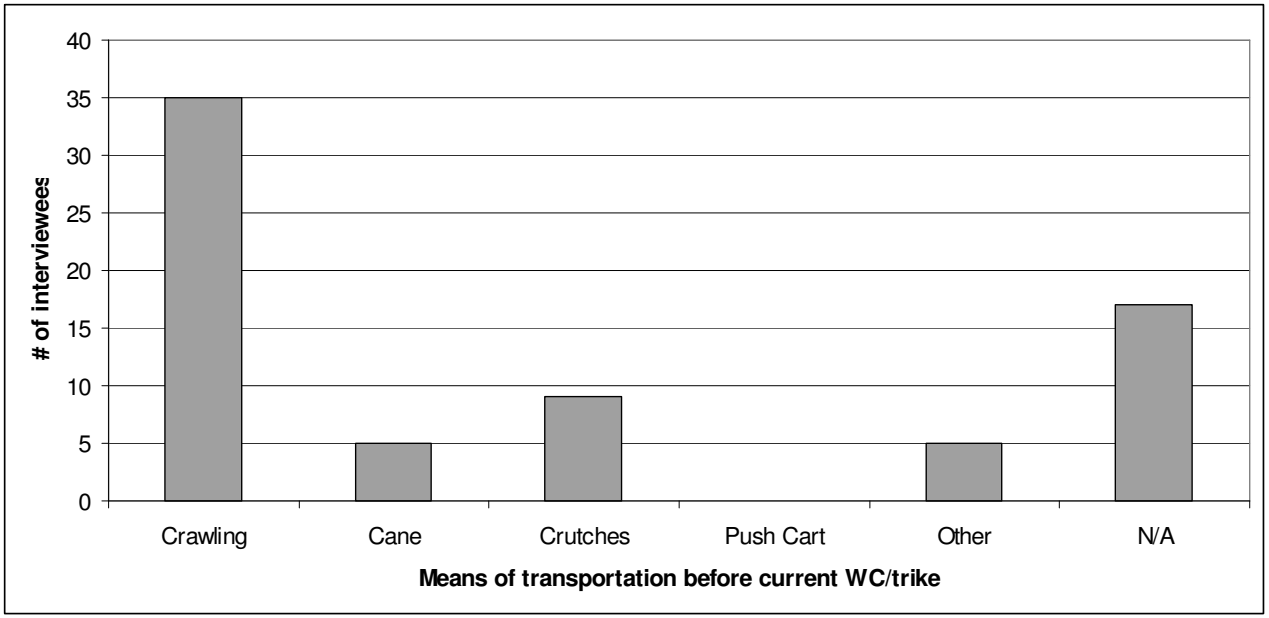
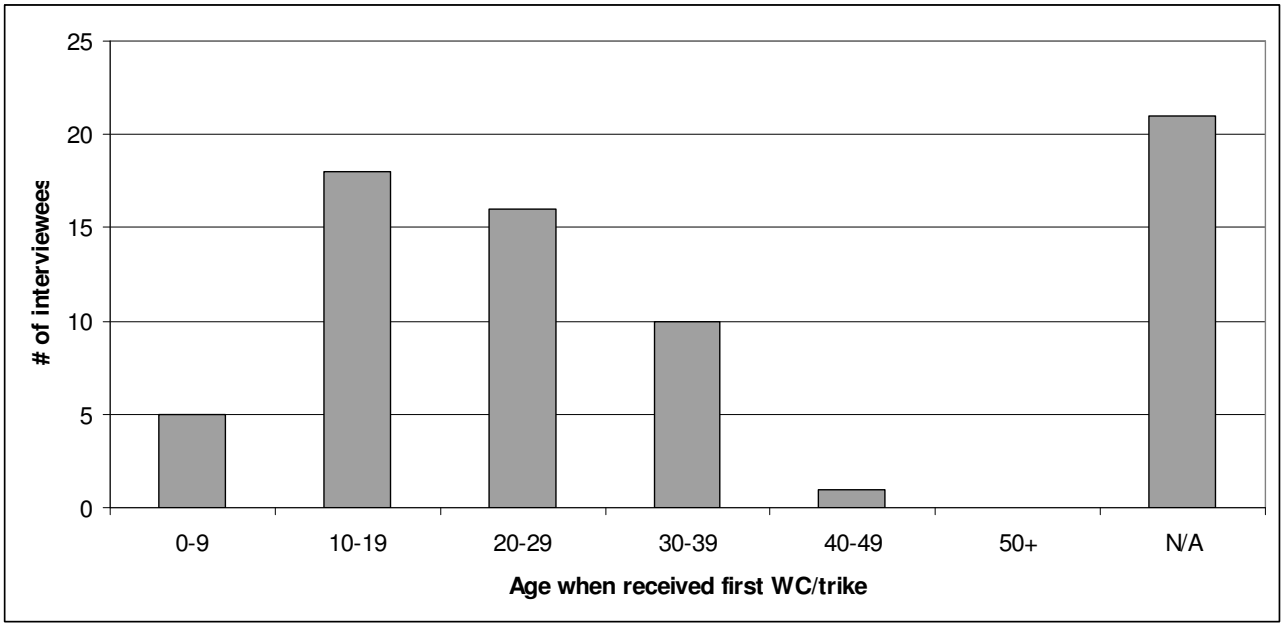
TZ WHEELCHAIR ASSESSMENT
Opportunities for improved distribution/procurement

- 65% crawled on the ground before current mobility aid
- Mean age when acquired first mobility aid is 21
- In TZ, 2,000 people have a wheelchair, 30,000 to 50,000 need one.





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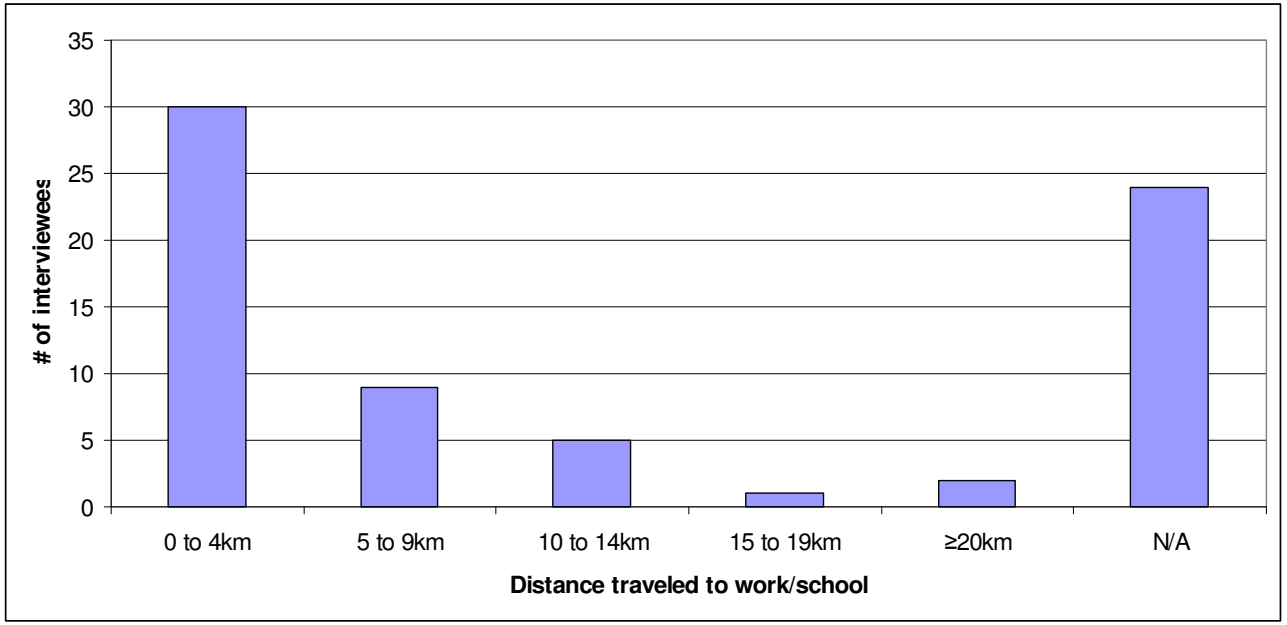
TZ WHEELCHAIR ASSESSMENT
Opportunities to better serve user needs

- 36% interviewees traveling more than 5km per day
- Largest fraction of interviewees (37%) using a tricycle
- Tricycles much more common (75% of sales at APDK, Kenya)



Tanzanian public bus

Tanzanian-made trike

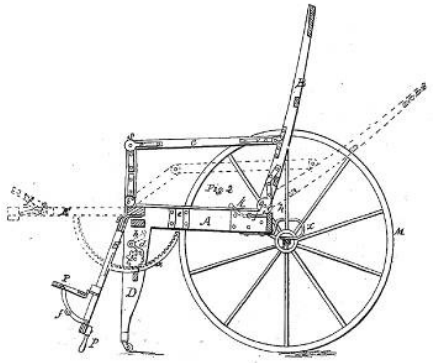
TZ WHEELCHAIR ASSESSMENT
Opportunity to design mobility aids to better serve users

Common mobility aids available in East Africa

USA/Europe designed, African made

African designed, African made

USA designed, foreign made



First USA wheelchair patent
A.P. Blunt, et. all., 1869

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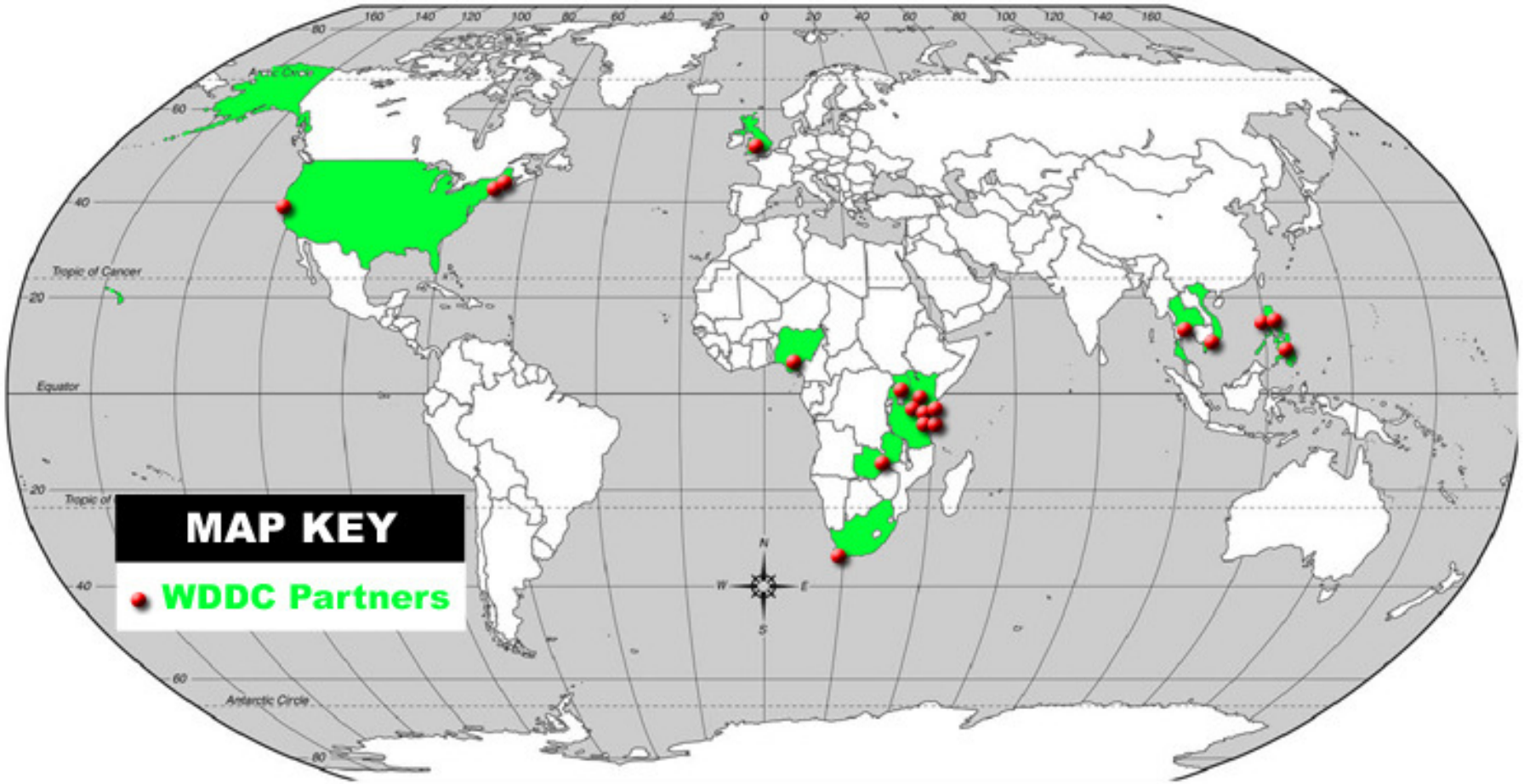
WHEELCHAIR DESIGN IN DEVELOPING COUNTRIES
Established in 2007

Motivation: Engage many bright students in advancing wheelchair technology

Activities of students in the class:

- Use science and technology to improve the lives of others
- Learn the technical, social, and economic factors preventing appropriate wheelchair technology from being implemented
- Study engineering, business, and biomechanics theory in context of wheelchairs
- Work in teams, collaborating with developing country partners and wheelchair specialists, to design and prototype wheelchair technology
- Interact with faculty, professional, and community partners during guest lecturers
- Participate in summer fellowships in developing countries to implement class projects

PARTNER WORKSHOPS
How class projects were defined



9 countries in Africa and Southeast Asia

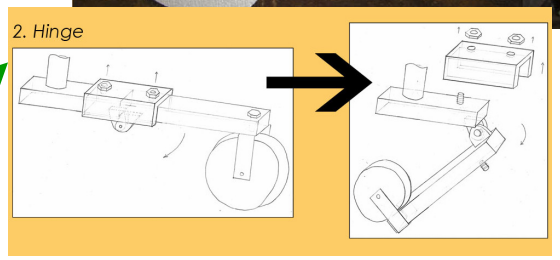
13 partner workshops

SP.784 WHEELCHAIR DESIGN IN DEVELOPING COUNTRIES
Class project cycle

1. Define projects with workshops (Aug-Sept)

Collaborate

Wheelchair experts



2. Develop ideas and prototype (Feb-May)

Students travel to workshops

3. Test and implement (June-July)

Disseminate

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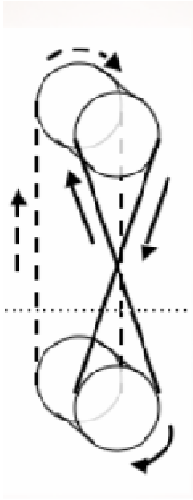
2007 CLASS PROJECTS

2-speed tricycle

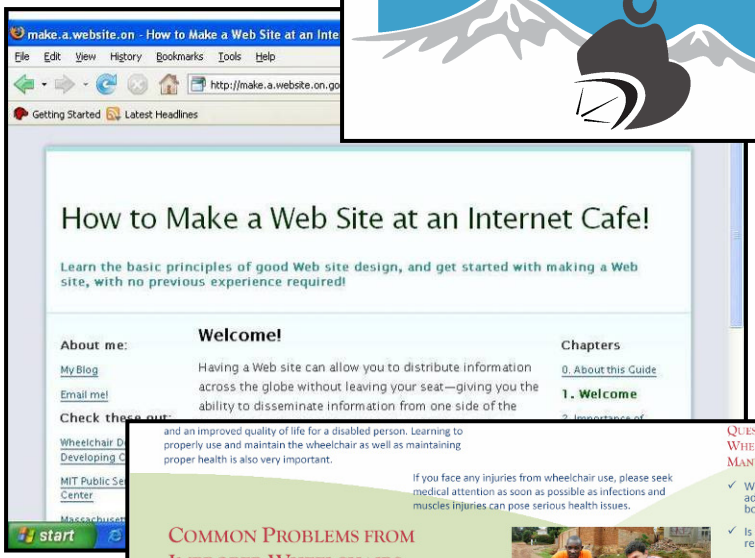
How it works

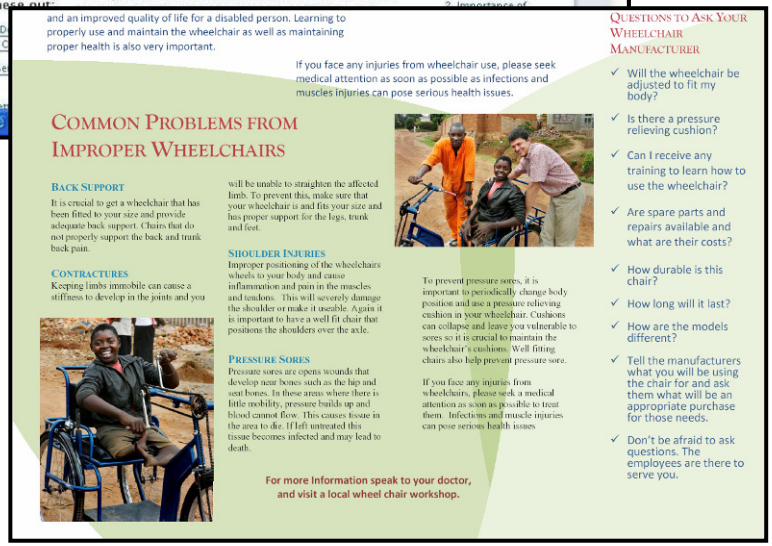
- Pedal forwards: you drive normally
- Pedal backwards: normal chain ratchets at wheel and figure-8 chain drives forward



Marketing strategies for workshops

KCMC WHEELCHAIRWORKSHOP





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2008 PROPOSED PROJECTS
1. World-wide network to connect donors local workshops

Objectives:

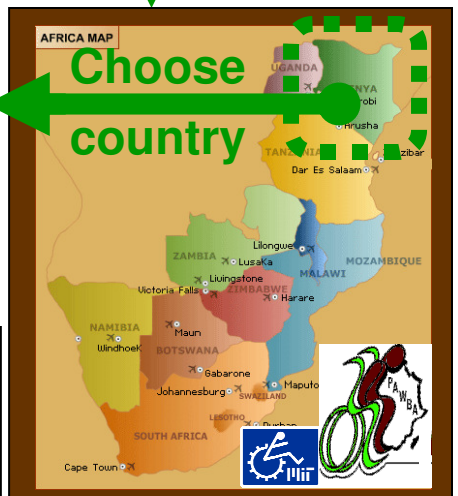
- Connect funds from international donors to local workshops
- Compete with large-scale donation organizations

Project details:

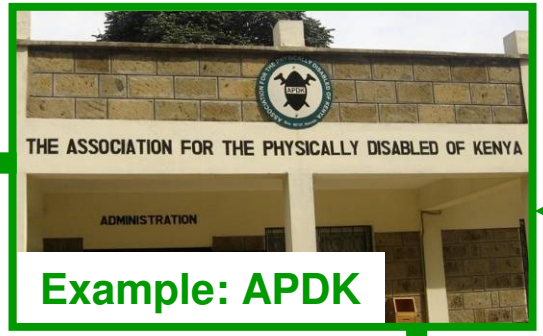
- Assess donation capability, user need, and develop business model
- No NGO required – **100% fund transfer**
- Inputs/outputs managed by donors and workshops through internet
- Workshops held accountable for confirming delivery of wheelchair

Foreign donor

Log on to network



Wheelchair network website



Example: APDK

Donate to client

Delivery confirmation to donor

Client

Provided: $50

Required: $150

Bio:

David is a polio survivor from Busia, Kenya. He requires a tricycle…

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2008 PROPOSED PROJECTS
2. Low-cost tricycle attachment

Objective: Design a new tricycle attachment that costs ~$20

Project details

- Low cost (~$20)
- Optimize usage of bicycle parts
- Connects to both 3 and 4 wheelers made in partner workshops
- Gear ratio appropriate for local conditions (may use 2-speed trike from last year's class)

2008 PROPOSED PROJECTS
3. Small businesses run from wheelchairs

Objective: Identify ways disabled people can buy their own mobility aid and use it to generate an income.

Ex) Mobility Care mobile phone credit seller chair

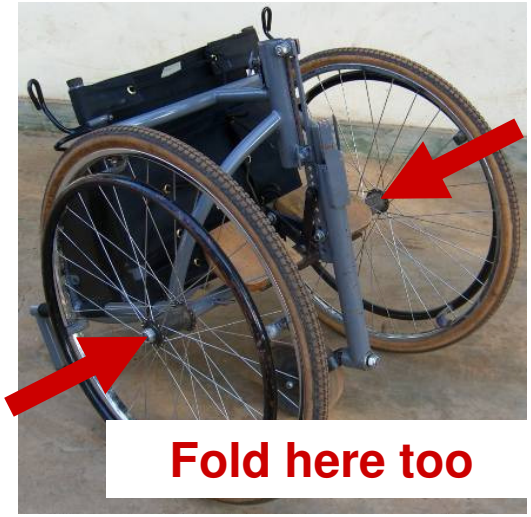
Ex) APDK retractable mobile phone tray

Project details

- Identify small business opportunities
- Develop business models for each wheelchair-based business
- Locate resources to allow people to buy own chairs
  - Micro loans
  - Pay-over-time plan from manufacturers
- Optimize usage of available materials and processes
- Work with mechanical engineers to prototype add-ons to wheelchairs to facilitate business

PROPOSED CLASS PROJECTS FOR 2008
4. Folding 3-wheeler

Objective: Modify the popular African-made three-wheeler to collapse like a 4-wheeled wheelchair



Project details

- Design a system to fold the rear wheels in closer to the frame
- Utilize bicycle parts and other local materials
- Cannot add significant weight or manufacturing cost to the chair
- Can use in conjunction with front wheel coupling developed in last year's class.
- Has to fit in the trunk of a car or in a bus

2008 PROPOSED PROJECTS
5. Wheelchair modifications for women

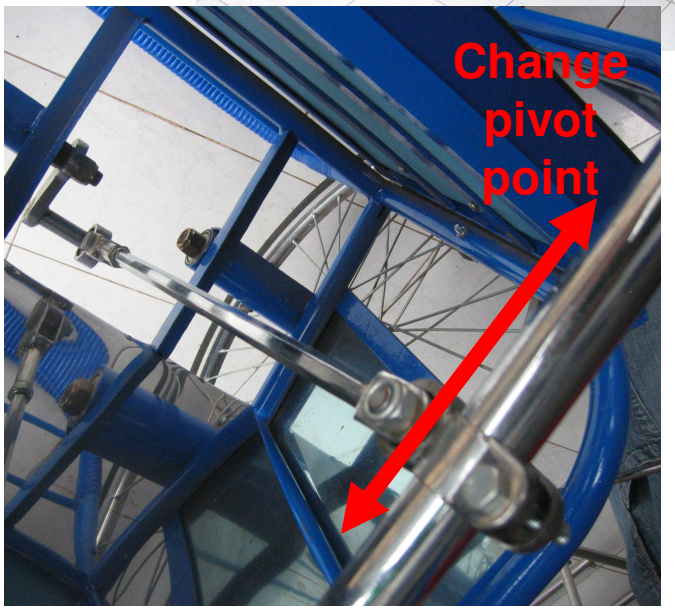
Objective: Design wheelchair accessories specifically for women's needs

Project details

- Enable user to easily get down to the floor
- Carry children
- Carry supplies/ groceries/water
- Removable to reduce weight
- Low-cost (~$20)
- Made from local components

2008 PROPOSED PROJECTS
6. Adjustable gear ratio for Kien Tuong tricycles

Objective: Enable the Kien Tuong tricycle to change gear ratios on the fly



Cool steering linkage

Project details

- Current tricycle only has one gear, but great steering/geartrain combo
- Kien Tuong would like a system to shift gears on the fly
- Can change gear ratio by moving pivot position
- Cannot add significant cost
- Made from local components

2008 PROPOSED PROJECTS
7. Small business assessment plan

Objective: Improve practices and efficiency of local workshops and identify supplemental income generating activities

APDK Kenya makes 200 wheelchairs per month, whereas most local shops make 10-20

Wheelchair workshops have the capacity to produce products like pedal-powered grinders and charcoal presses

Project details

- Create a general assessment system to optimize local wheelchair builders for their region
- Investigate the local market – clients, funders, materials, labor skill, etc.
- Determine whether to build wheelchairs locally, import from larger African manufacturers, or import from Asia
- Identify supplemental income sources from related products, such as charcoal compactor or pedal grinders

2008 PROPOSED PROJECTS
8. Curriculum to teach wheelchair prescription

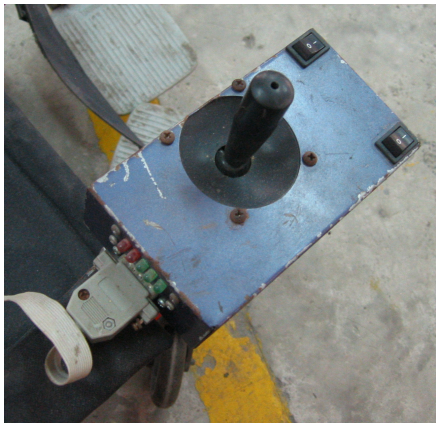
Objective: Design a short course to train wheelchair prescribers

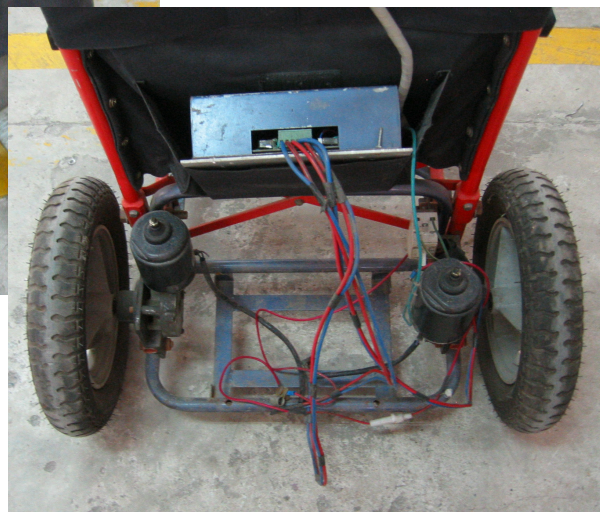
Project details

- Develop a curriculum to teach people how to prescribe wheelchairs for different disabilities
- Offer different levels of training (similar to PADI)
- Make prescriber also salesman for products
- Train prescribers so they can be posted far away from workshop, as to utilize central manufacturing
- Write for people with english as a second language
- Class to be taught by wheelchair technicians

2008 PROPOSED PROJECTS
9. Electrically powered wheelchair/scooter

Objective: Design an appropriate electric wheelchair/scooter





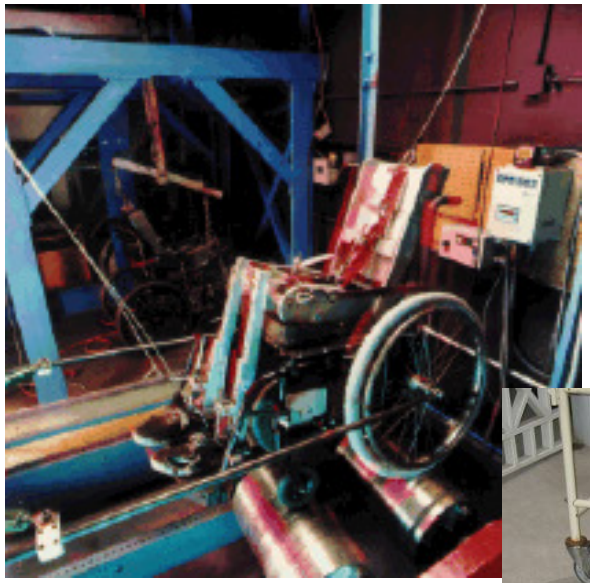
Wheelchair made by Thaiwheel

Project details

- Use locally available motors and batteries
- Develop control system and user interface
- Small enough to use indoors, through doorways
- Possibly use solar power
- Low-cost (~$300-500)

2008 PROPOSED PROJECTS
10. Creating testing methods and instruments

Objective: Design protocols and instruments to test the appropriateness of wheelchairs in developing countries



Double drum tester

Imported wheelchair

Project details

- All tests have to low-cost and made from local materials
- Modify double-drum test for rough-road testing
- Test max user weight for chairs
- Use tests to determine appropriateness of donated chairs
- ISO certify locally made chairs
- Test bearings for life under harsh conditions (wet, mud, sand, dust, etc)

2008 PROPOSED PROJECTS
11. Sports wheelchairs and tricycles

Objective: Design new mobility aids purely for recreation

Freedom Technology Racer

Disacare sports wheelchairs

OneOff Titanium handcycle

Project details

- Wheelchairs for tennis or basketball
- Wheelchairs should conform to international competition standards
- Tricycles made for sport or commuting or possibly off-road
- All products made low-cost out of local materials
- Ideally produce jigs and production manuals for products

2008 PROPOSED PROJECTS
12. Organizational and logistical improvements

Objective: Optimize the logistics of workshop production and improve product quality

Stock material at APDK

DAGE workshop

Project details

- Track manufacturing quality and customer satisfaction by using serial numbers to trace product defects back to the workers
- Implement a computerized stock room and purchasing system
- Purchase in bulk to lower unit cost of components
- Outsource fabrication of some components to specialty shops
- Apply lean manufacturing techniques

2008 PROPOSED PROJECTS
13. Optimized tricycle biomechanics

Objective: Improve functionality, comfort, and efficiency of tricycles.

Aligned or opposed hand cranks?

WDDC 2-Speed design

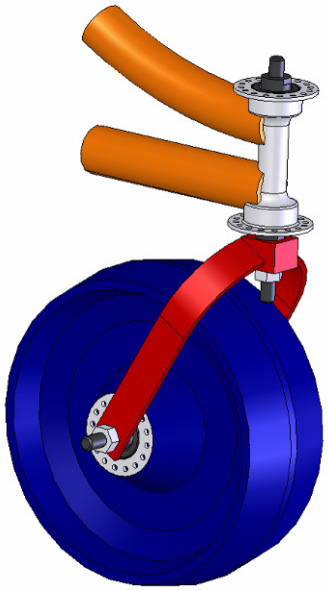
Project details

- Upper body motion with highest sustainable power output
- Gear ratio for different terrains
- Best configuration of hand grips
- Best rake angle for stability vs. comfort
- Appropriate, supportive seating
- Simplified production

PROPOSED PROJECTS
14. Component and material optimization

Objective: Find best components and materials to reduce weight, improve serviceability, extend life, and lower cost.

Available materials



Castor barrel-bike hub concept

Project details

- How can bicycle components be used more effectively in wheelchairs?
- What components are available
- How could they be used differently
- Life and durability
- Cost savings of replacement

2008 PROPOSED PROJECTS
15. Welding jig and symmetric frame design

Objective: Decrease manufacturing time with better, more repeatable welding jigs and simplified frame designs.

Current Whirlwind jig with separate left and right sides

Project details

- Assess current process time and manufacturing steps
- Identify bottlenecks in production
- Find unnecessary frame complexity
- Tolerance stack-up and mitigation
- Simplified frame prototype
- Jig design prototype
- Process plan for making frames

2008 PROPOSED PROJECTS
16. Tricycle frame jig and production manual

Objective: Design jig to hold tricycle components during welding and make a production manual to teach other workshops to make tricycles.

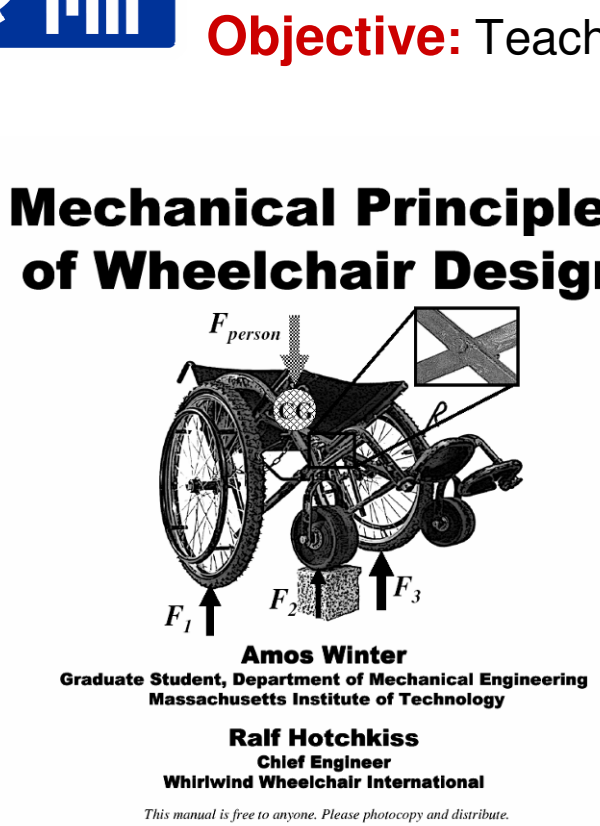
Tricycle frame production, APDK Nairobi

Project details

- Understand tricycle building process
- Design to avoid tolerance stack-up mitigation
- Accommodate bending errors
- Calculate process complexity and time
- Produce a simplified frame prototype
- Produce a jig design prototype

PROPOSED PROJECTS
17. Workshop manual

Objective: Teach safe manufacturing practices



Example: Manual to teach mechanical engineering principles

Project details

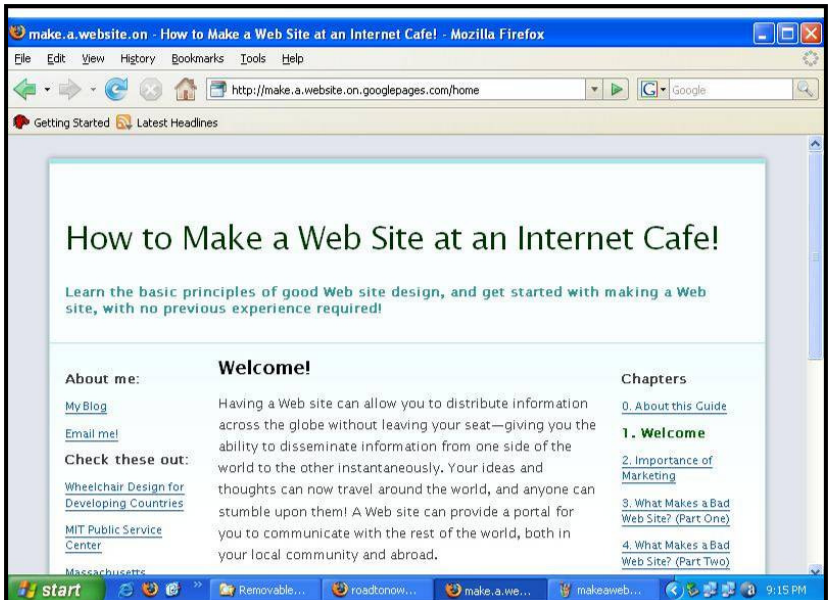
- Consider language, literacy, and cost of printing
- Demonstrate unsafe practices in workshop
- Describe manufacturing processes
- Explain tolerance stack-up mitigation, bending errors
- Introduce lean manufacturing principles

PROPOSED PROJECTS
18. Marketing plan

Objective: Increase awareness of locally-made mobility aid products

KCMC WHEELCHAIRWORKSHOP

Logo design made in 2007



http://make.a.website.on.googlepages.com

Project details

- Study other successfully marketed appropriate technology (ex. Treadle pump)
- Identify potential forms of media in Africa vs. USA
- Advertise to foreign donors
- Create materials for brochures, posters, TV, and radio
- Create websites that can be maintained by workshops (consider internet speed)

PROPOSED PROJECTS
19. Break design

Objective: Improve reliability and safety of breaks

Reverse break

Break lever

Drum break

Flip break

Project details

- Examine existing bike breaking systems
- Calculate stopping requirements
- Understand road surfaces
- Consider manufacturing cost/complexity and tire wear
- Prototype break for both tricycles and wheelchairs

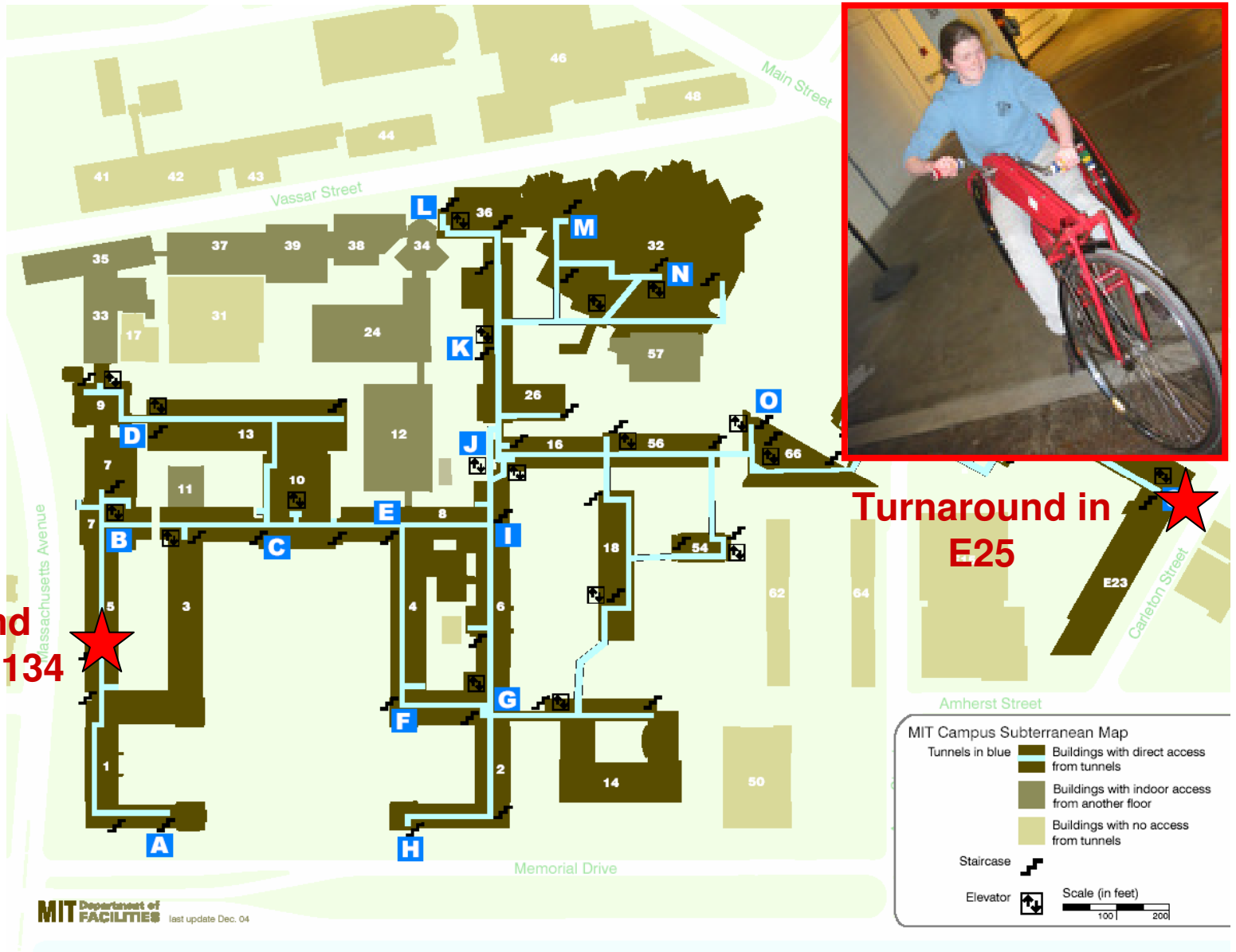
Have an Idea?

- Write it down and we will include it when projects are chosen

HOMEWORK
Due at beginning of next class

- Pick your top 5 projects
  - Projects will be ranked by popularity
  - Project teams formed next Thursday 2/14 
- Readings (posted on course website)
  - International Society of Prosthetics and Orthotics (ISPO): “Wheelchair” article
  - Whirlwind Wheelchair International: “Proposal to develop standards for wheelchair provision services” article
  - A. Winter: “Assessment of wheelchair technology in Tanzania”

NEXT CLASS
Wheelchair relay race



February 5, 2008