
SP.784 WHEELCHAIR DESIGN
IN DEVELOPING COUNTRIES
SPRING 2007
web.mit.edu/sp.784/www

COURSE INFO

Lecturers: Amos Winter, Graduate Student, Mechanical Engineering
Amy Smith, Senior Lecturer, Mechanical Engineering

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

Lecture: Required, can miss two, but not more without instructor permission

Lab: Presentation times chosen next class. Lab groups choose own time

Homework: Primarily readings and short assignments. Most time for projects

Grading: Final course grades will be P/D/F Class

- Participation/homework: 15
- Strategy presentation: 20
- Concept presentation: 20
- Most Critical Module (MCM) Presentation: 20
- Final presentation and prototype: 25

Course website: http://web.mit.edu/sp.784/www/index.html

PROJECT

Team: 4 to 5 members with lab instructor

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

Deliverables:

- PowerPoint presentation for the Strategy, Concept, MCM, and Final prototype.
- Poster for The Museum of Science in Boston on Sat, May 12
- Prototypes: Physical solution to each teams' MCM for MCM presentation. Working prototype for final presentation

RESOURCES

Monetary: $2000 for prototyping
IDEAS Grants (Generator dinner Feb 13)

Manufacturing:

The Edgerton Center
Student Shop

THE HOBBY SHOP

Parts: African wheelchairs and bicycle components

Storage: Currently, room 3-446. Combination is 5-3-4.

FELLOWSHIPS

- 3 to 6 available
- Bring WDDC technology back to African workshops
- Work in any or all 7 partner shops
- ~10 weeks
- Apply through PSC Fellowship process

SYLLABUS

Week	Lecture date	Wheelchair topics	Guest lecturer
1	2/9/2007	Introduction to wheelchairs in developing countries	
2	2/16/2007	Designing wheelchairs for the developing world	Alison Hynd - PSC Fellowships
3	2/23/2007	Wheelchair Biomechanics/Ergonomics	
4	3/2/2007	Abdullah speaking to the class about his experiences	Abdullah Munish, TATCOT
5	3/9/2007	Appropriate Technology	Amy Smith, MIT
6	3/16/2007	Available materials and manufacturing techniques in	Prof. Mary Boyce, Mike Tarkanian,
7	3/23/2007	Successful implementation of technology in developing	Sarah Bird, Amy Banzaert, MIT
8	3/30/2007	Spring Break	
9	4/6/2007	Machine Design	Prof. David Gordon Wilson, MIT
10	4/13/2007	Business plans in the developing world	Jorge Barrera, MIT
11	4/20/2007	Ralf speaking to the class about his experiences	Ralf Hotchkiss, Whirlwind
12	4/27/2007	Wheelchair user image	Prof. David Wallace, MIT
13	5/4/2007	Project work	
14	5/11/2007	Project work	
15	5/18/2007	Project work	

Principle areas of lectures

- Engineering
- Business
- Biomechanics
- Local considerations

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)

MY INVOLVEMENT IN WHEELCHAIR 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

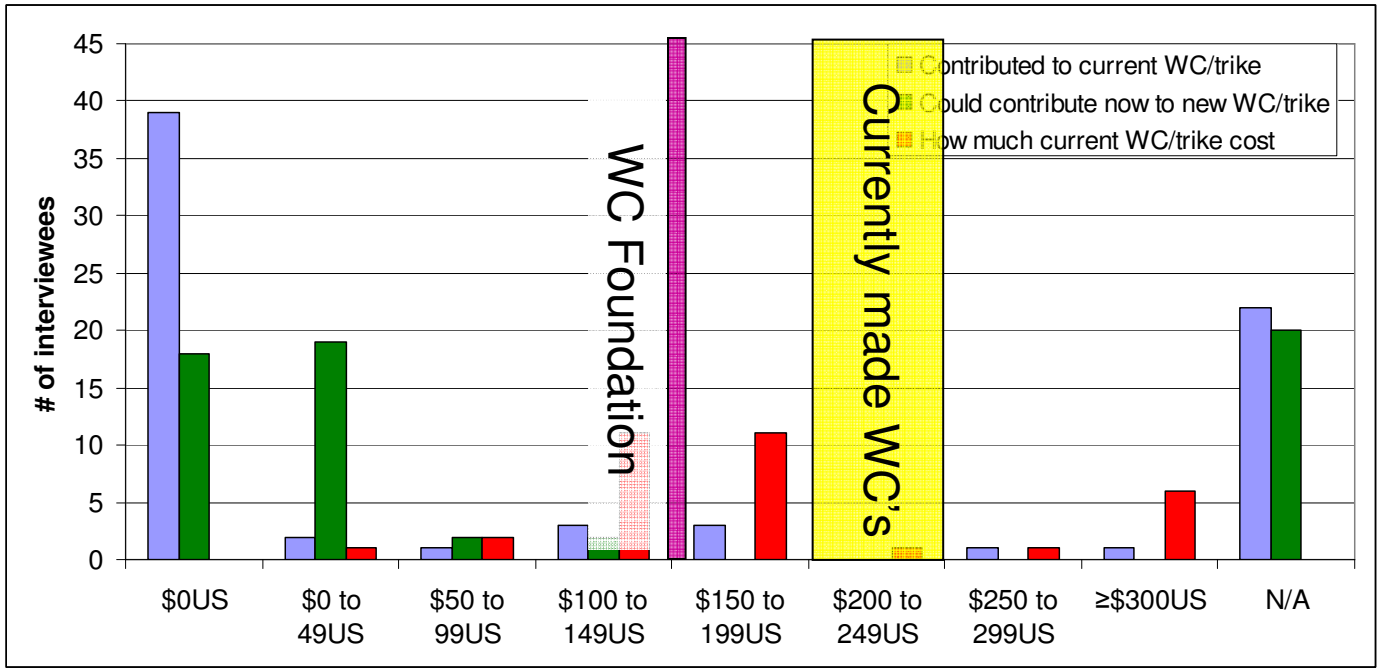
Parties interviewed

Wheelchair users

Wheelchair workshops

Wheelchair advocacy groups

TZ WHEELCHAIR ASSESSMENT
Identified usage problems



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

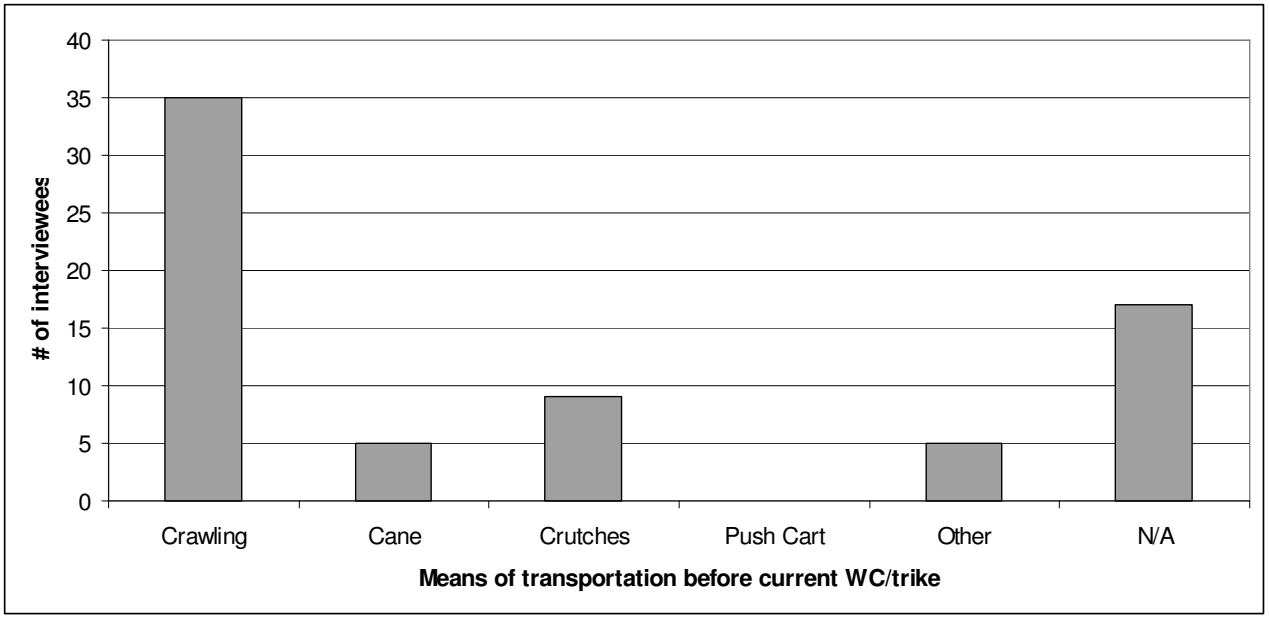
Largest donor in TZ

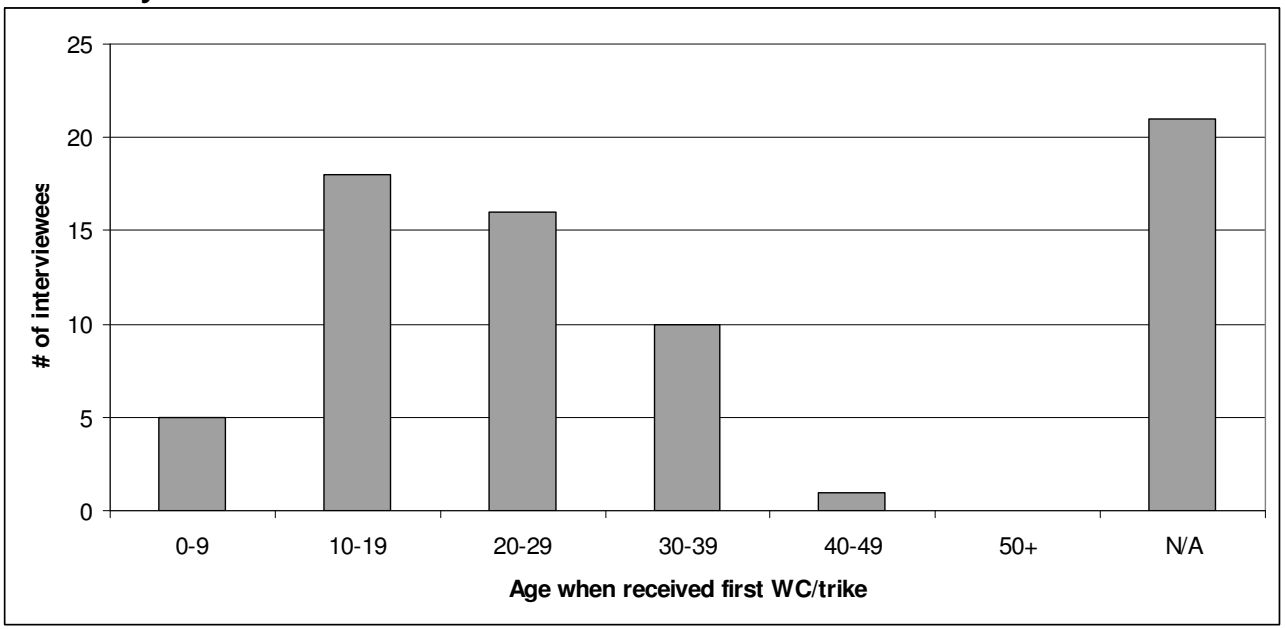
Wheelchair Foundation
"Serving the World"
hope
Circling the Globe with Friendship
mobility

- 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 handcycles

TZ WHEELCHAIR ASSESSMENT
Acquiring a mobility aid

- 65% crawled on the ground before having a 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.
- Polio most common cause of disability in interviewees

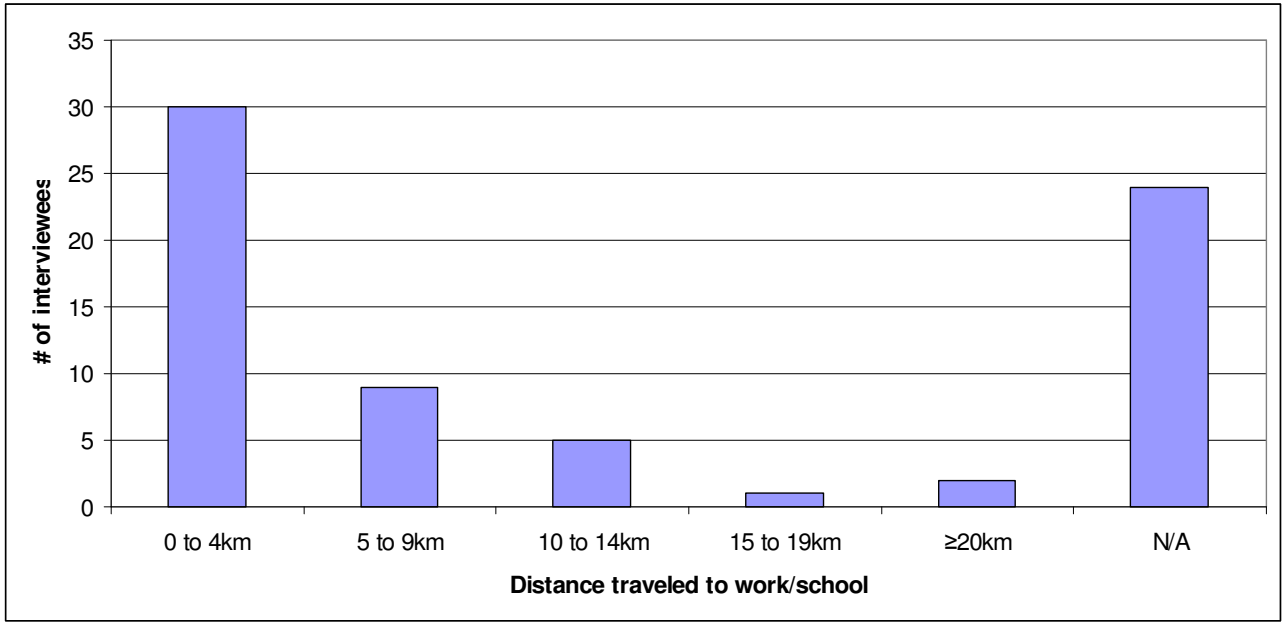




February 9, 2007

TZ WHEELCHAIR ASSESSMENT
Different usage practices than in developed world

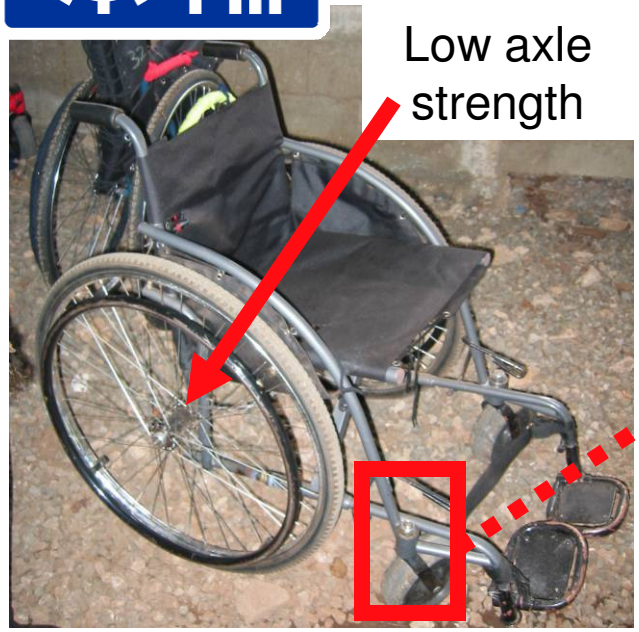
- 36% interviewees traveling more than 5km per day
- Largest fraction of interviewees (37%) using a tricycle
- Tricycles much more common (75% of sales in Kenya)



Tanzanian public bus

Tanzanian-made trike

TZ WHEELCHAIR ASSESSMENT
Identified technical problems



Imported chairs not strong, no spare parts

TZ WHEELCHAIR ASSESSMENT
Business/production problems

- Requires 4.5 man-days to produce TZ wheelchair
- Kenyan APDK tricycle produced in ~11 man-hours
- Typical shop produces ~10 units per month, APDK in Kenya produces ~100 and will soon be at 180.
- Donated chair and tricycle same price ($150), so why donate?
- Average TZ annual income is $288 USD (UNICEF, 2003)

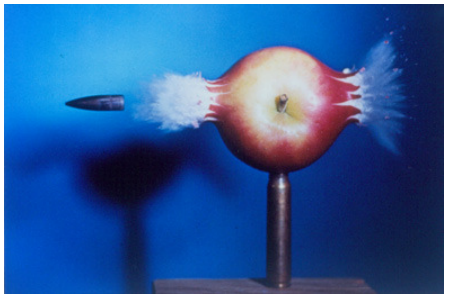
Mobility Care workshop, Tanzania

APDK workshop, Kenya

WHY TEACH A CLASS ON WHEELCHAIR TECH?

Motivation: By partnering with expert organizations, MIT can help make great improvements to wheelchair technology in developing countries

Technical expertise



MIT

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

Experience

Whirlwind Wheelchair International

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

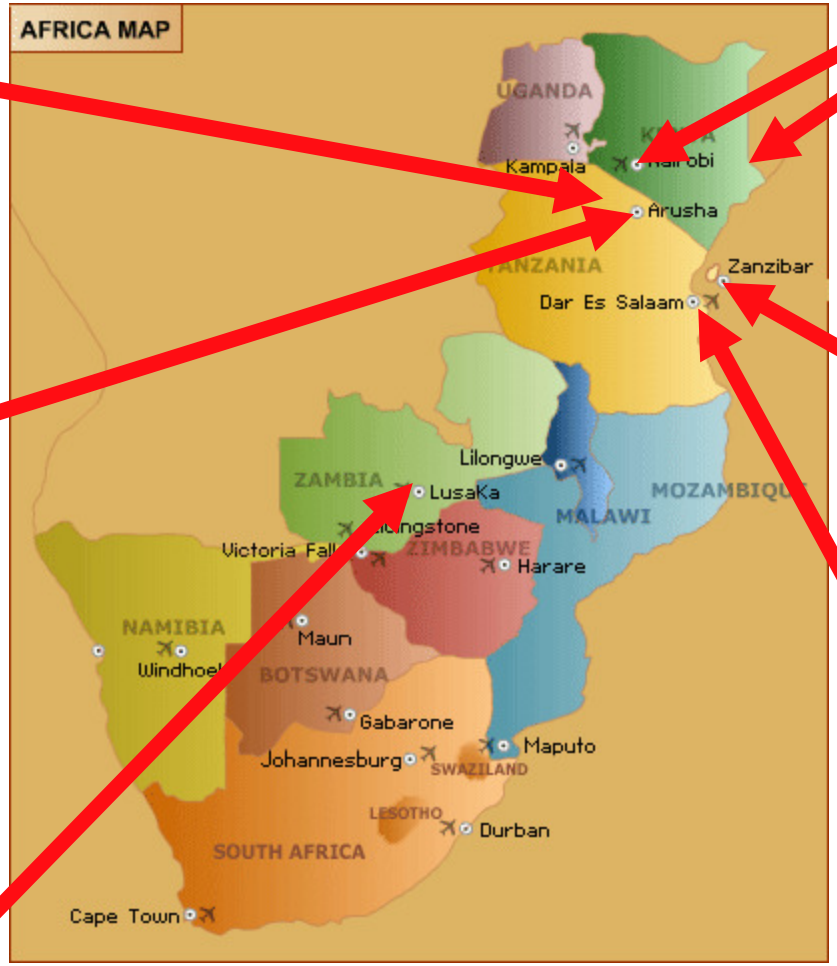
Local knowledge

Tanzania Training Center for Orthopedic Technologists

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

AFRICAN PARTNER WORKSHOPS
How class projects were defined

Workshop locations



Mobility Care

KCMC

Disacare

APDK

UWZ

DAGE

CURRENTLY USED TECHNOLOGY
Most common mobility aids available in East Africa

Whirlwind (USA)
designed, locally made

Locally designed,
locally made

Motivation (UK)
designed, locally made

Wheelchair
Foundation,
foreign
designed,
made in
China

Free
Wheelchair
Mission
(USA), made
in China

PROPOSED PROJECTS
1. Small businesses run from wheelchairs

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

APDK retractable mobile phone tray

Considerations

- Small business identification
- Resources to allow people to buy own chairs
  - Micro loans
  - Pay-over-time plan from manufacturers
- Available materials and processes

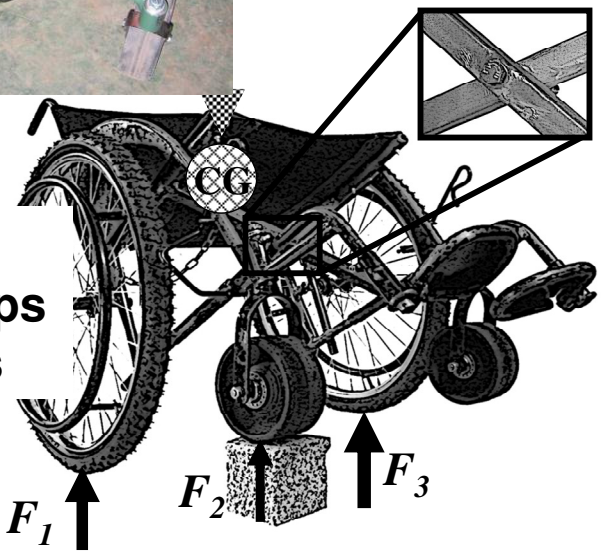
Deliverables

- Multiple businesses and mechanical add-ons to existing mobility aids
- Production time estimates and plans for add-ons
- Payment plan for buying chair

PROPOSED PROJECTS
2. Folding three-wheeler

Objective: Modify the popular African-made three-wheeler to have a folding frame.

3-wheeler kinematically constrained with ground



4-wheeler folds, but tips on bumps

Considerations

- Production times and complexity
- Added material and production cost
- Weight compared to current
- Available materials/processes
- Appropriate folding size

Deliverables

- Frame prototype to be integrated into currently used components
- Production process that can be brought to Africa

PROPOSED PROJECTS
3. Optimized tricycle biomechanics

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

Aligned or opposed hand cranks?

Considerations

- Upper body motion with highest sustainable power output
- Gear ratio for different terrains
- Best configuration of hand grips
- Process plan/manufacturing complexity
- Available materials
- Best placement relative to torso
- Best seating position

Deliverables

- Prototype that can be integrated into both TZ, KE, ZM tricycles
- Production process that can be brought to Africa

PROPOSED PROJECTS
4. Tricycle frame redesign

Objective: Improve strength, stiffness, weight, saftety, and cost of tricycle frames.

Collapsed tricycle frame

Considerations

- Optimal strength/weight ratio of available tubing
- Overall weight
- Overall size and maneuverability
- Manufacturing time and complexity compared to current
- Accessibility in and out of seat
- Integration with drive system and small business opportunities

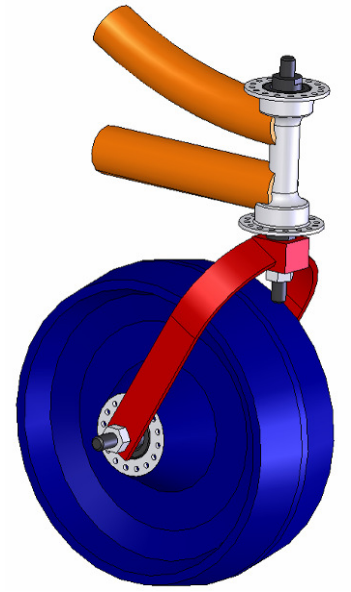
Deliverables

- Frame prototype to be integrated with current components or other available components
- Integrated with drive system
- Process plane to bring to Africa

PROPOSED PROJECTS
5. 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

Considerations

- What components are available
- How could they be used differently
- Life and durability
- Cost savings of replacement

Deliverables

- Prototypes of improved systems
- Incorporation into other teams' projects

PROPOSED PROJECTS
6. Workshop business plans

Objective: Increase the profitability and efficiency of workshops.

Supplemental product: Disacare sports wheelchairs

Considerations

- Comparison of successful vs. struggling workshops
- Identify supplemental income opportunities
- Examine processes and # employees
- Identify grant opportunities
- Assess market for mobility aids

Deliverables

- Business plan tuned to partner workshops

PROPOSED PROJECTS
7. 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

Considerations

- Assess current process time and manufacturing steps
- Identify bottlenecks in production
- Find unnecessary frame complexity
- Tolerance stack-up and mitigation

Deliverables

- Simplified frame prototype
- Jig design prototype
- Process plan for making frames

PROPOSED PROJECTS
8. 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

Considerations

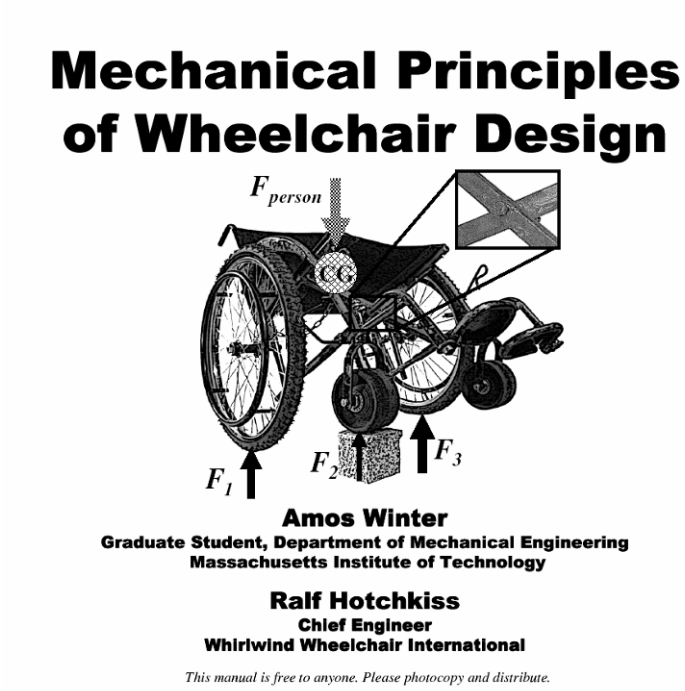
- Tricycle building process
- Tolerance stack-up mitigation
- Accommodate bending errors
- Process complexity and time

Deliverables

- Simplified frame prototype
- Jig design prototype
- Process plan for making frames

PROPOSED PROJECTS
9. Workshop manual

Objective: Teach safe manufacturing practices



Example: Manual to teach mechanical engineering principles

Considerations

- Language and literacy
- Cost of printing
- Unsafe practices in workshop
- Understanding manufacturing processes
- Tolerance stack-up mitigation
- Accommodate bending errors
- Process complexity and time

Deliverables

- Simple, concise manual
- Easily distributed and reproducible

PROPOSED PROJECTS
10. Marketing plan

Objective: Increase awareness of locally-made mobility aid products

mobility care

Wheelchairs made in Africa for Africa

The alternative

MobilityCare wheelchairs are made of locally available materials. They are fitted with common bicycle tires that are available in any village. Each model can be tailor-made to suit the client's needs.

About MobilityCare

MobilityCare aims to works with established health institutions. Orthopedic departments can consult MobilityCare about the size and type of wheelchair needed. The home-situation of a wheelchair applicant should be assessed before and after obtaining a wheelchair.

MobilityCare encourages sponsor organisations to opt for durability by subsidising local wheelchair purchase. Buying a locally-built wheelchair means an investment in local capacity building.

MobilityCare also offers training and helps technicians to start wheelchair production workshops. Gradually this should lead to a regional service network.

For disabled people here in Tanzania a wheelchair makes the difference between being stuck at home and having the freedom to get out. An opportunity to go to the market, to school, to work… and the chance to live a better life

Technicians who know how to use and how to make a wheelchair. They guarantee user-friendly products.

The problems in the past

In Africa most wheelchairs are imported from overseas. In general they are not suited to the local conditions: the small front wheels get stuck in mud or sand and spare-parts are often not available. Sooner or later most grind to a halt. The disappointed owner finds out that a new tire is not for sale locally or the materials used cannot be repaired, and the wheelchair is abandoned.

MobilityCare models from left to right:: 3-wheeler adults, 3 wheeler children and foldable wheelchair

MobilityCare
P.O. Box 14408
Arusha
Phone 0748-203133
mobilitycare@wheelchairs.co.tz

Mobility Care homepage

Considerations

- Other successfully marketed appropriate technology (ex. Treadle pump)
- Best forms of media in Africa vs. USA
- Budget constraints of workshops
- Advertising to foreign donors
- Identifying advertising venues

Deliverables

- Advertising plan
- Sample advertisements
- Possibly a website

PROPOSED PROJECTS
11. Break design

Objective: Improve reliability and safety of breaks

Reverse break

Break lever

Drum break

Flip break

Considerations

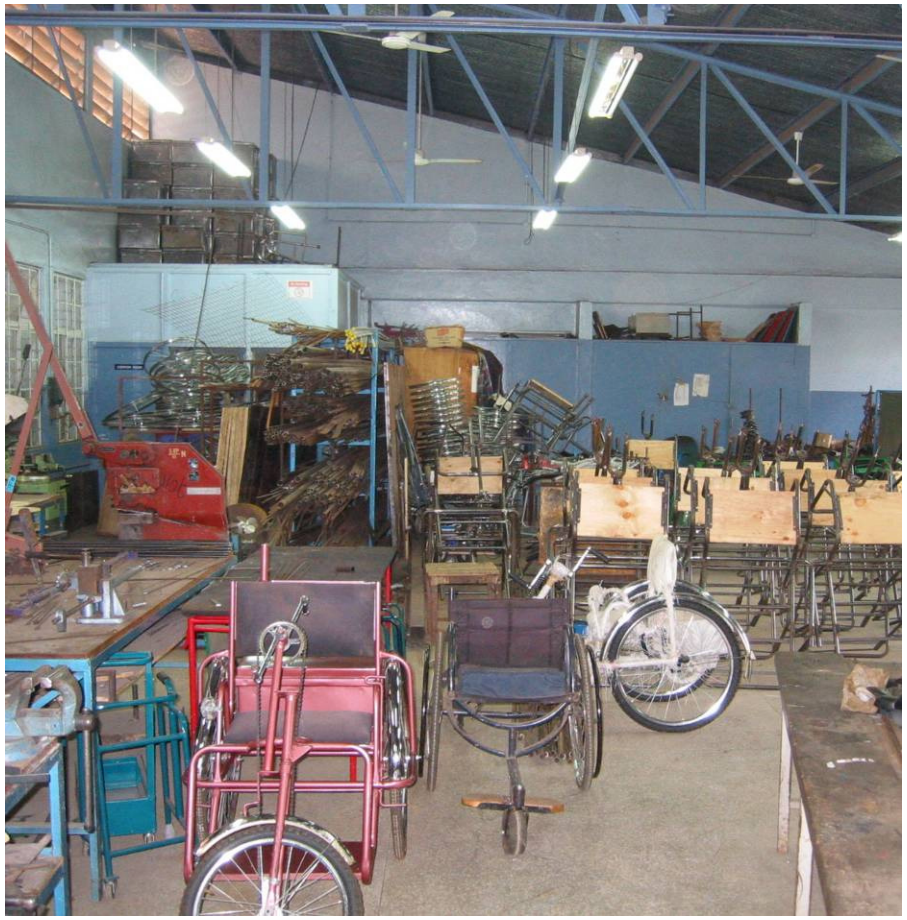
- Existing bike breaking systems
- Stopping requirements
- Road surfaces
- Manufacturing cost/complexity
- Tire wear

Deliverables

- Prototype break for both tricycles and wheelchairs
- Process plan to use in Africa

PROPOSED PROJECTS
12. Manufacturing optimization

Objective: Reduce time and streamline manufacturing process



APDK Workshop

Considerations

- Current processes
- Available machinery
- Labor skill
- Product design complexity
- Available outsourcing

Deliverables

- Full process plan for both wheelchair and tricycle
- Optimized shop layout

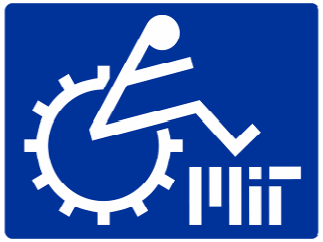
Have an Idea?

- 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 class

- 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”



CLASS ACTIVITY
Cross-campus wheelchair relay

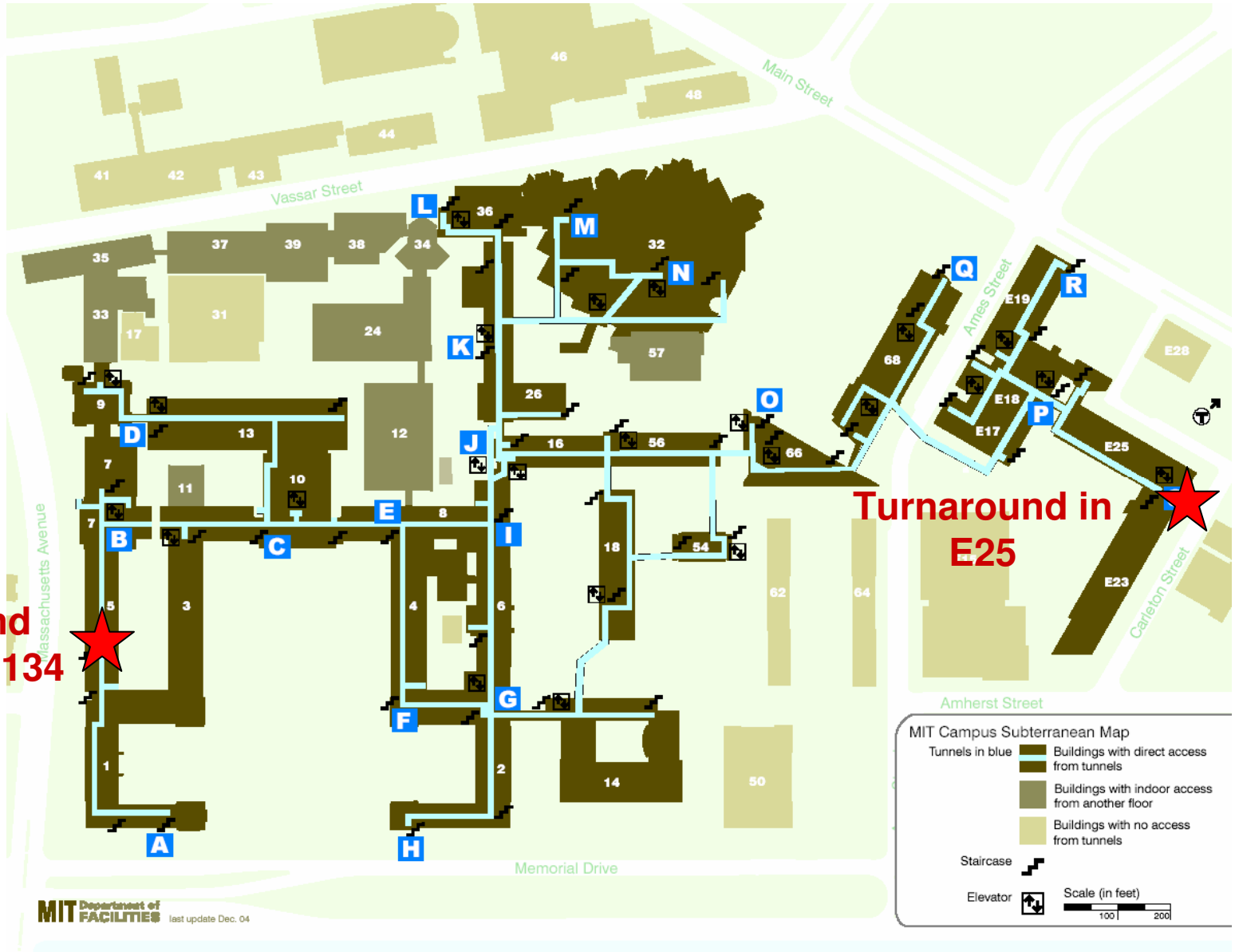
Objective: Understand the difficulties of using a mobility aid

Rules:

- Each team will be assigned a mobility aid
- The team has to travel from 5-134 to the basement of E25. The turnaround point is the base of the stairwell by MIT Medical, where some soda machines are located (see map)
- Teams will be released in 30second intervals from 5-134
- Each team must have a designated "rider" at all times
  - Rider does not have use of his/her legs
  - Rider can be carried or pushed
  - As a rider, only ask for help when you need it. Try to visualize what you would/would not be comfortable with if you were disabled
- Each team has to visit a bathroom and have their rider sit on a toilet for 30seconds (actually using the toilet is not required)
- A team can switch riders as many times as they want
- Each member of the team has to be the rider for a minimum of 3 minutes during the race
- Elevators cannot be used
- Teams must switch mobility aids at E25
  - The first team to arrive has to wait for the second team
  - The second team gives their mobility aid to the first team, and waits for the third team
  - The third team gives their mobility aid to the second team and receives the first team's original chair. They wait for the fourth team.
  - Process repeats through all teams until the last team receives the first team's original chair
- The team that returns back to 5-134 first gets to eat the first!
- Be respectful! This is not a joke. Be careful when you race so no one gets hurt.

February 9, 2007

CLASS ACTIVITY
MIT tunnel map



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