



**SP.784 WHEELCHAIR DESIGN
IN DEVELOPING COUNTRIES
SPRING 2007**



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



PROJECT

Team: 4 to 5 members with lab instructor

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



Courtesy of Whirlwind Wheelchair International. Used with permission.

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:



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. , \$ i ` c Z ` h \ Y ` k c f ` X f i g ` X] g U V ` Y **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% of people 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)

February 9, 2007



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)





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



Map courtesy of CIA.

Parties interviewed



Wheelchair users



Wheelchair workshops

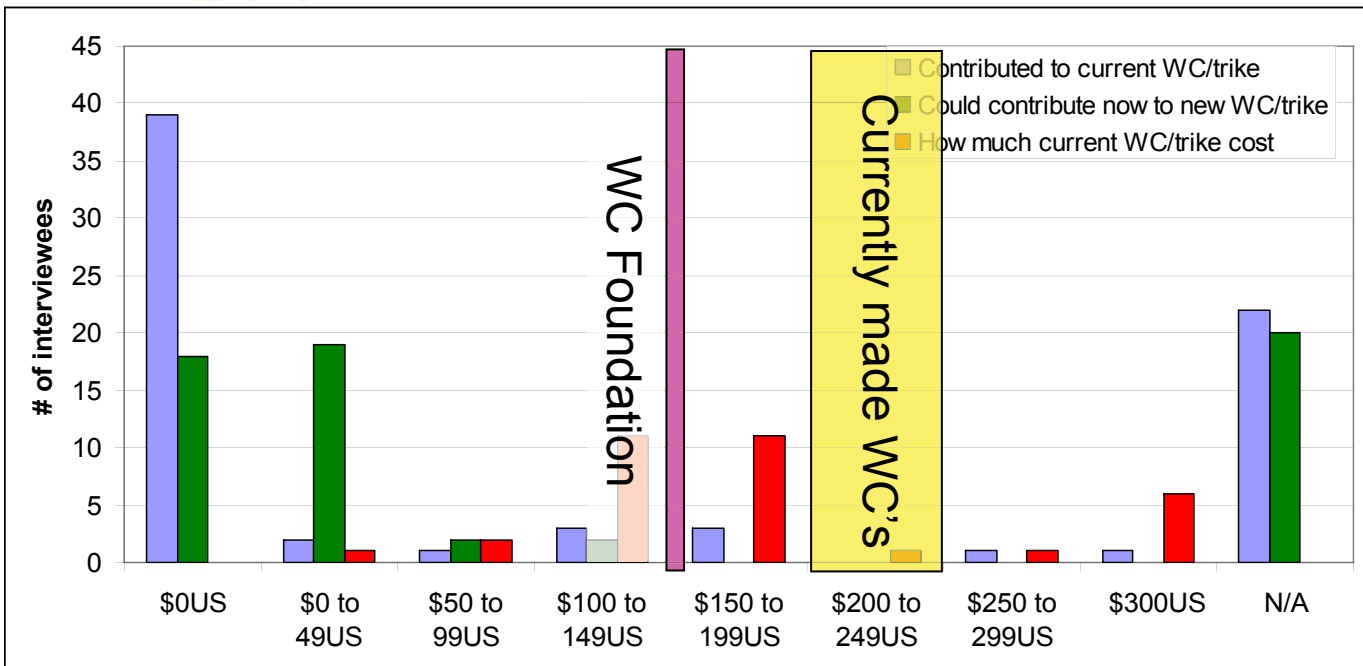


Wheelchair advocacy groups



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

- 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

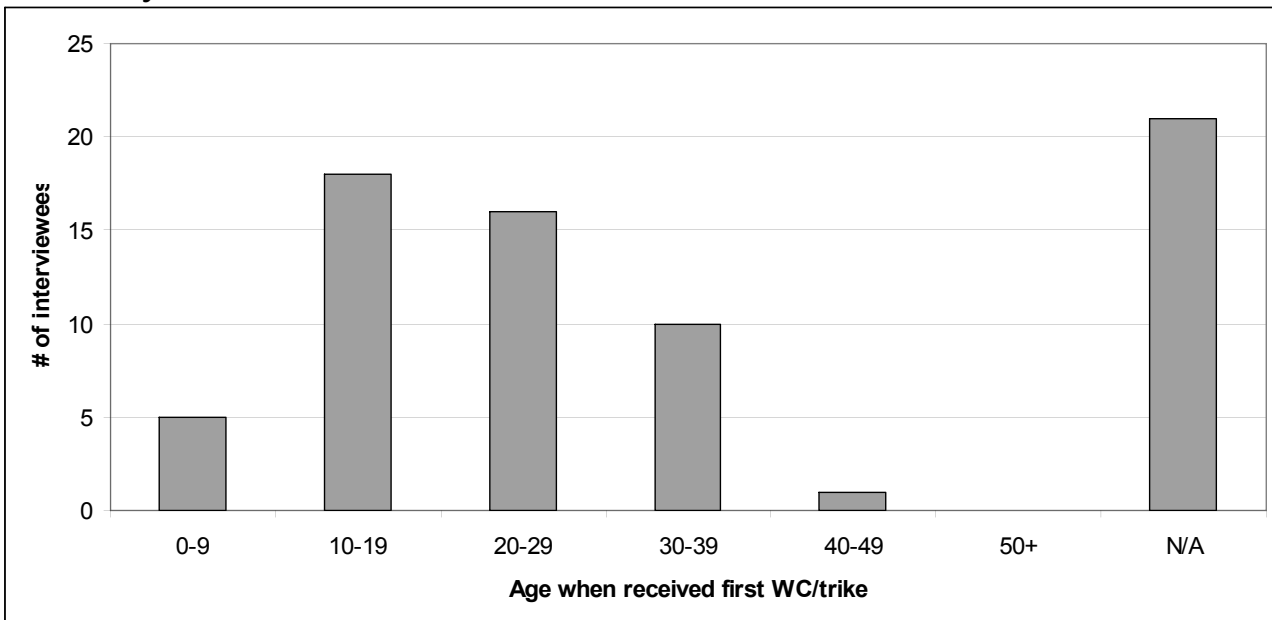
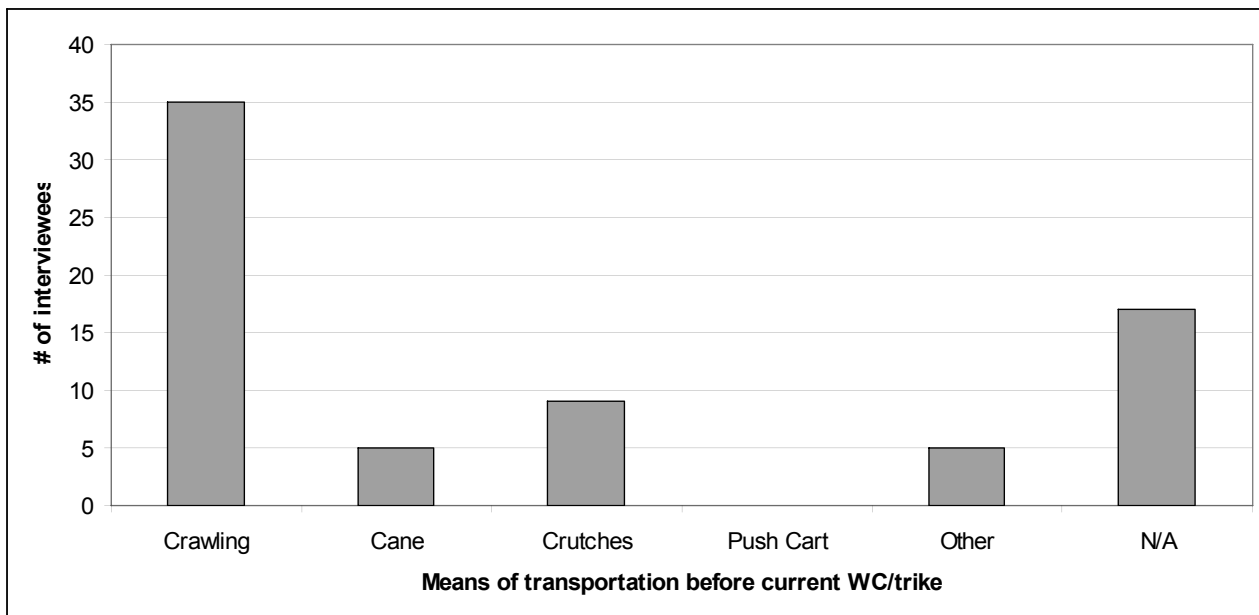


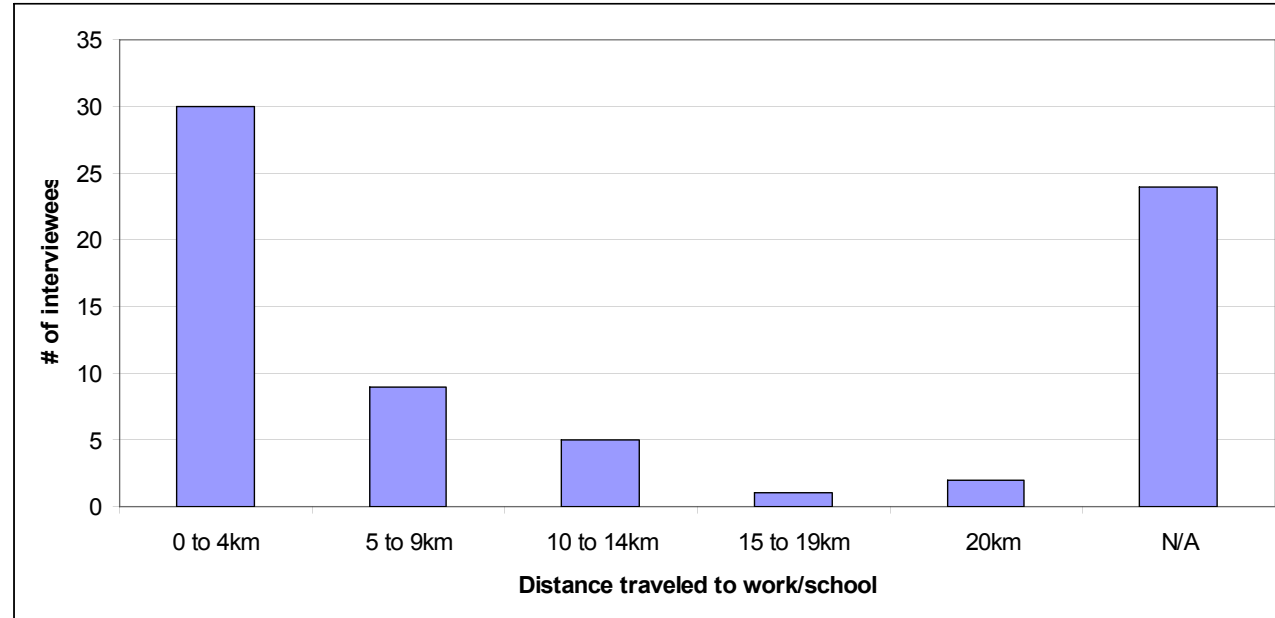
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TZ WHEELCHAIR ASSESSMENT

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

Courtesy of Brother Rewd (<http://www.flickr.com/photos/brotherrewd/207471616/>)





TZ WHEELCHAIR ASSESSMENT

Identified technical problems

Low axle strength



Over-constrained bearings

Inefficient gear ratios



Imported chairs not strong, no spare parts



Frame weakness



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**



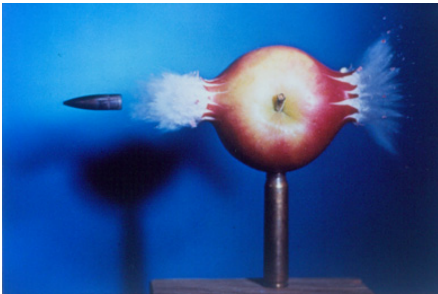
**APDK
workshop,
Kenya**



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

Mobility Care

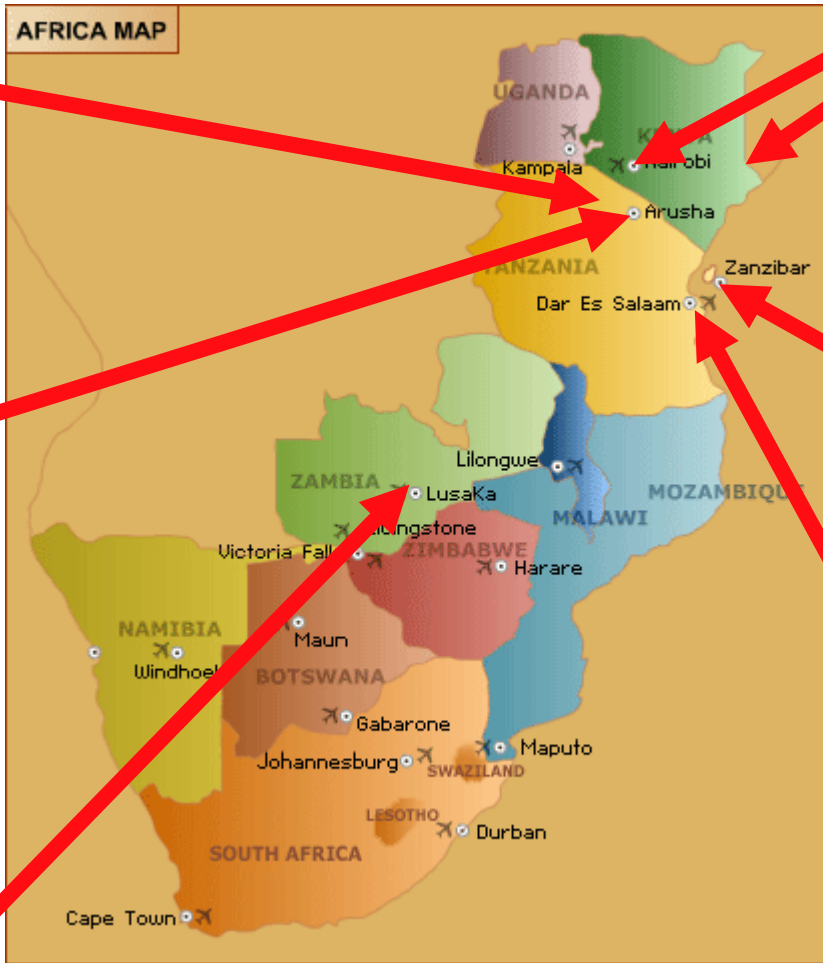


KCMC



Disacare

Workshop locations



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**



**Free
Wheelchair
Mission
(USA), made
in China**

Image removed due to copyright restrictions. Photo of chair by Free Wheelchair Mission (<http://www.freewheelchairmission.org>).



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. : c ` X] b [` h \ f Y Y ! k \ Y Y ` Y f

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



' ! k \ Y Y ` Y f
kinematically
constrained
with ground

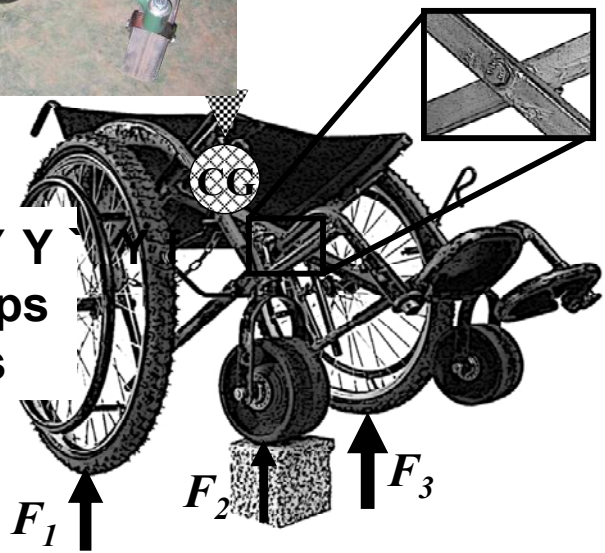
Considerations

- 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

(! k \ Y Y ` Y f
folds, but tips
on bumps





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, safety, 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 plan to bring to Africa



PROPOSED PROJECTS

5. Component and material optimization

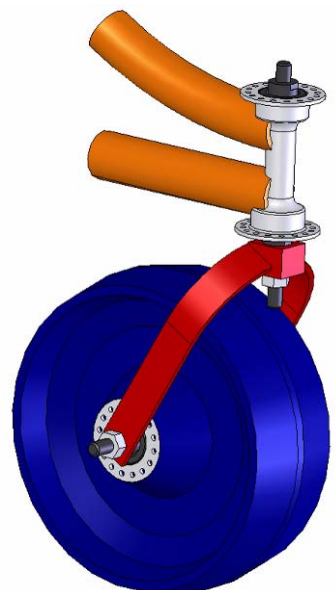
Objective: Find best components and materials to reduce weight, improve serviceability, extend life, and lower cost.



Available materials

Considerations

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



Castor
V U f f Y ` ! V] _ Y
hub concept

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

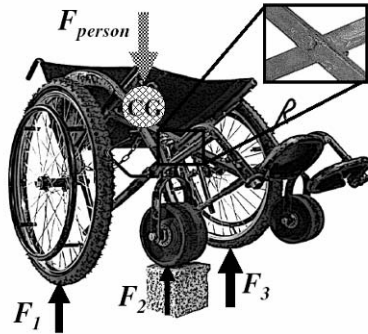
- Tricycle building process
- Tolerance stack-up mitigation
- Accommodate bending errors
- Process complexity and time

Deliverables

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

Objective: Teach safe manufacturing practices

Mechanical Principles of Wheelchair Design



Amos Winter
Graduate Student, Department of Mechanical Engineering
Massachusetts Institute of Technology

Ralf Hotchkiss
Chief Engineer
Whirlwind Wheelchair International

This manual is free to anyone. Please photocopy and distribute.

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

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

Image removed due to copyright restrictions.
Old version of Mobility Care homepage.

Mobility Care homepage



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

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Objective: Understand the difficulties of using a mobility aid

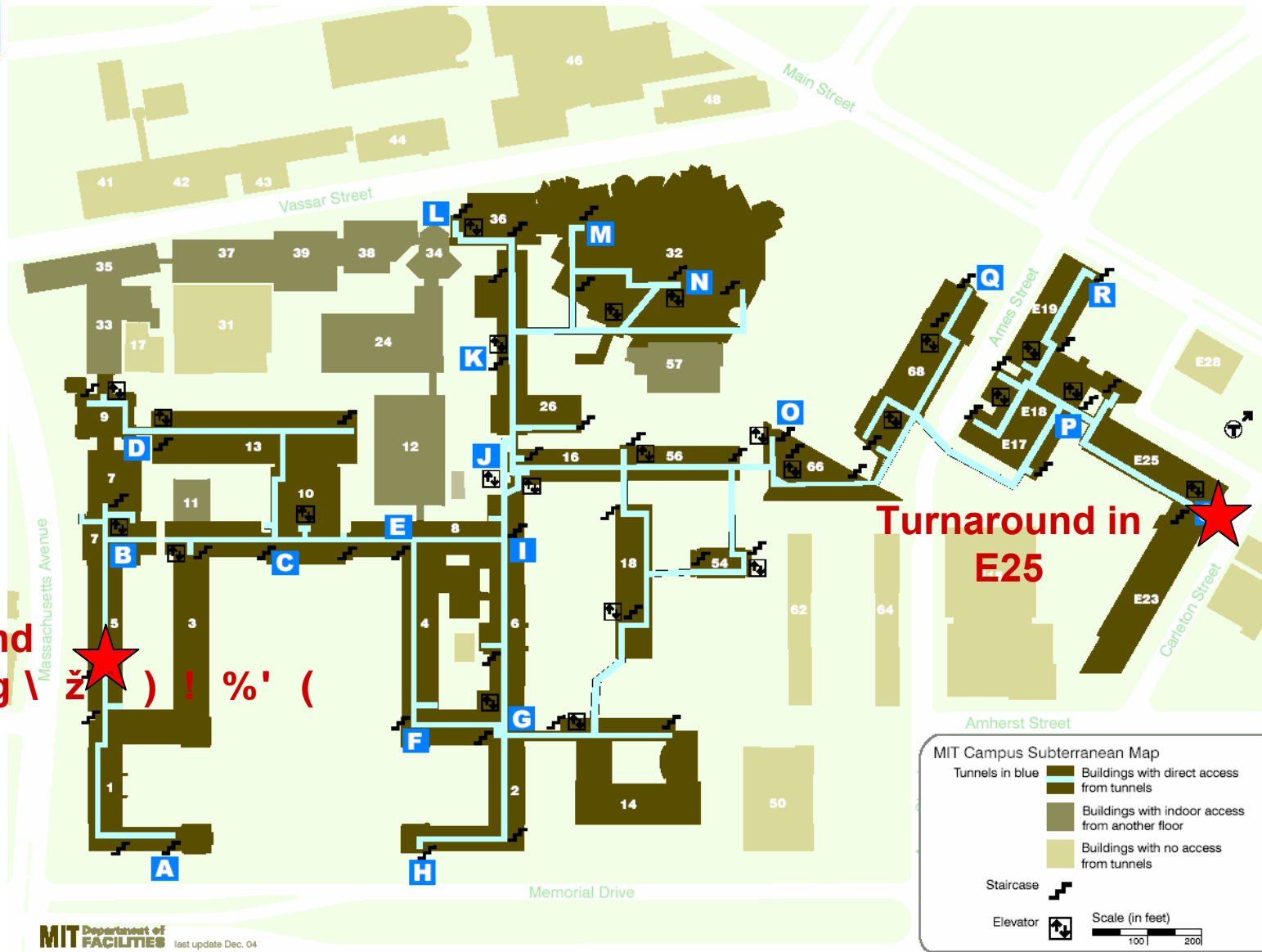
Rules:

- 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.**



CLASS ACTIVITY MIT tunnel map

Start and
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MIT Department of FACILITIES last update Dec. 04