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
**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
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.
• 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
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<td>Introduction to wheelchairs in developing countries</td>
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<td>Designing wheelchairs for the developing world</td>
<td>Alison Hynd - PSC Fellowships</td>
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**Principle areas of lectures**

- Engineering
- Business
- Biomechanics
- Local considerations
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)
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)
• 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)
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

MY INVOLVEMENT IN WHEELCHAIR TECHNOLOGY
Summer 2005: Assessment of WC technology in Tanzania

February 9, 2007
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”

- 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
• 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

TZ WHEELCHAIR ASSESSMENT
Acquiring a mobility aid

Means of transportation before current WC/trike

Age when received first WC/trike

# of interviewees

0 5 10 15 20 25 30 35 40
Crawling  Crutches  Push Cart  Other  N/A

# of interviewees

0 5 10 15 20 25
0-9 10-19 20-29 30-39 40-49 50+ N/A

February 9, 2007
• 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)
Over-constrained bearings

Low axle strength

Inefficient gear ratios

Frame weakness

Imported chairs not strong, no spare parts

TZ WHEELCHAIR ASSESSMENT
Identified technical 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)
**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
CURRENTLY USED TECHNOLOGY
Most common mobility aids available in East Africa

- Whirlwind (USA) designed, locally made
- Motivation (UK) designed, locally made
- Wheelchair Foundation, foreign designed, made in China
- Free Wheelchair Mission (USA), made in China

February 9, 2007
Objective: Identify ways disabled people can buy their own mobility aid and use it to generate an income.

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

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.

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

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

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.

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

Supplemental product: Disacare sports wheelchairs

Deliverables
• Business plan tuned to partner workshops

February 9, 2007
**Objective:** Decrease manufacturing time with better, more repeatable welding jigs and simplified frame designs.

**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

Current Whirlwind jig with separate left and right sides
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.

**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

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

Example: Manual to teach mechanical engineering principles
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
**PROPOSED PROJECTS**

11. Break design

**Objective:** Improve reliability and safety of breaks

**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

Considerations
• Current processes
• Available machinery
• Labor skill
• Product design complexity
• Available outsourcing

Deliverables
• Full process plan for both wheelchair and tricycle
• Optimized shop layout

APDK Workshop
Have an Idea?

- Write it down and we will include it when projects are chosen
• 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 30 second 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 30 seconds (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