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Abstract

The purpose of this assessment was to determine the current state of wheelchair technology in Tanzania and the factors that prevent Tanzania's disabled from utilizing wheelchair technology. Interviews of wheelchair and tricycle users, wheelchair and tricycle manufacturers, and advocacy groups for the disabled were conducted during the study. Technical issues identified after compiling the interview data included: tricycles are more popular and much less expensive than wheelchairs; most disabled rely on donations to buy a mobility aid; production costs can be decreased by using bicycle components and outsourcing tasks; bicycle components are available in rural areas and are attractive for use in wheelchairs; the Wheelchair Foundation irresponsibly distributes wheelchairs and does not use appropriate technology.

Technical recommendations are offered as solutions to issues raised by interviewees. Designs that replace all of the radial bearings in current wheelchairs with bicycle components are presented and verified with engineering calculations. Lean manufacturing practices that reduce cost and production time are outlined. A next-generation wheelchair with tricycle attachment that fulfills the needs of Tanzanian wheelchair users is discussed. Strategies for increasing wheelchair technicians' mechanical engineering knowledge and promote design improvement at the workshop level are introduced.

1 Introduction

1.1 Background

People with mobility disabilities in developing countries face many challenges in integrating into everyday life. If these people cannot afford to purchase a wheelchair, they are sometimes forced to stay trapped in their home. Disability KaR[1], which is helping to oversee wheelchair projects in developing countries, reports that only 2% of people in Africa who need a wheelchair actually have one. The Tanzania Association of the Disabled (CHAWATA) estimates there are 30,000 people who need wheelchairs in Tanzania alone.[2] Immobility adversely affects the lives of disabled people by, for example, making it near impossible to attend school, participate in their communities, or earn an income. Some Tanzanians have makeshift mobility devices such as pushcarts, but the terrain in developing countries can be difficult to navigate; in urban environments, doorways and bathrooms are typically not handicapped accessible, and in rural settings roadway quality can be hilly, rough, and muddy. Many other disabled people have no mobility device at all, and are forced to crawl wherever they travel or stay trapped in their homes.

Although there are some wheelchairs available in Tanzania, the chairs are often imports that are poorly made, improperly fitted, and dangerous to the user. An abundance of low-quality chairs can be the result of charitable distributions from abroad that are more focused on the number of chairs circulated rather than the benefit to the users. Wheelchairs need to be fitted with the consideration of the rider's size, age, and nature of disability, among other factors. If improperly fitted, the chair can cause pressure sores – breaks in the skin produced by a person's weight pressing against an unyielding surface. These sores can develop almost immediately upon contact. If left untreated they can become open, deep sores and even lead to death.

Fortunately, efforts have been made in Tanzania to improve wheelchair technology, fabrication, and the channels through which wheelchairs are distributed. The Wheelchair Technologists Training Course (WTTC) at the Training Center for Orthopedic Technologists (TATCOT),[3] developed in part by the mobility products development non-governmental organization (NGO), Motivation,[4] is a one-year course for a Certificate for Wheelchair Technologists. The WTTC covers design, manufacturing, and fitting of wheelchairs made especially for African countries, which can be produced in small-scale, self-sustained shops. Whirlwind Wheelchair International (WWI),[5] a US-based non-profit NGO that develops appropriate wheelchair technology for developing countries, has helped establish 21 wheelchair manufacturing shops around the world. One of the wheelchair designs taught in the WTTC is based on a WWI model. Whirlwind is interested in expanding its technology in Tanzania through continued collaboration with TATCOT and possibly expanding the number of wheelchair manufacturing shops.

1.2 Purpose

The purpose of this assessment is to elucidate the factors in current wheelchair design, manufacturing, distribution, and use that are prohibiting Tanzanian wheelchair riders from accessing and utilizing appropriate wheelchair technology. Such factors can be in the form of technological inadequacies for the operating environment, inefficient manifesting practices, lack of competitive pricing, ineffective or limited cost subsidizing, inefficient distribution practices, etc. This report identifies many of the factors that hinder wheelchair use and the issues behind such problems, and then proposes appropriate technological solutions.

The methodology and focus of the study was mainly from an engineering perspective. The process of identifying problems with current wheelchairs and devising engineering solutions was treated as a mechanical design exercise. The Investigator does not purport to elucidate the social, cultural, and political factors surrounding wheelchair design, manufacturing, and use. The issue of wheelchair technology was viewed through an engineering lens. While not necessarily a limitation, the Investigator feels that it is important to be honest about the degree to which one really can “elucidate” ALL factors surrounding these problems.

This report was written to give feedback to TATCOT and WWI on current wheelchair technology in Tanzania. The hope is that TATCOT can use the information presented here to improve the content, technology, and practices taught in the WTTC and better understand the competing wheelchair technologies in the country. For WWI, this report will ideally serve as a design review of their technology currently being used, so they can improve future wheelchair designs. Finally, this report is meant to strengthen the relationship between TATCOT and WWI and to act as a catalyst for future collaboration. To the knowledge of the investigators, such an assessment has never been conducted in Tanzania.

1.3 Assessment strategy

1.3.1 Interview content

The aim of this assessment was to inspect the current state of wheelchair technology from all angles through interviewing the primary parties involved with wheelchair design, manufacturing, and use. Three types of questionnaires were developed by the Investigator and the Supervisors to interview individual wheelchair users, wheelchair advocacy groups, and wheelchair manufacturers. A short content summary for each party’s questionnaire is below. Each complete questionnaire is presented in Appendix A.

- **Individual wheelchair users:** How was the chair obtained; who paid for the chair, who made the chair; at what age was the chair obtained; what type of mobility is the chare used for – short or long travel; how functional is the wheelchair in the users life; what types of technical problems are encountered; what caused the disability; at what age was the first and current chair obtained.

- **Wheelchair Advocacy groups:** What services are provide to wheelchair users; does the organization purchase wheelchairs; are wheelchairs donated to the org – and if so by whom; does the org have a need-based subsidizing plan; how many people are in the org; how many wheelchairs have been distributed; are there any technical problems observed with the members' chairs.

- **Wheelchair manufacturers:** What types of wheelchairs are produced; how much does each cost; what types of components are being used; what types of raw material is used; how quickly are chairs produced; what types of manufacturing strategies are in use; how many people are employed.

1.3.2 Interview locations

An effort was made to interview a representative population of wheelchair users for the assessment. The interview locations are shown in Figure 1.1. These locations were chosen in an effort to represent both urban and rural wheelchair operating environments. In reality, visiting remote villages and interviewing disabled was logistically impossible. Advocacy groups working in rural areas provided most of the information about rural wheelchair use. Some rural information was contributed by urban interviewees who had lived much of their life in the village. Although not explored in this report, the inequalities between urban and rural disabled people merits further investigation. The majority of interviews were conducted in the Dar es Salaam area because it has the highest population density and concentration of wheelchair related organizations in the country.

Figure 1.1 Interviewing regions

Individuals and organizations that were interviewed were initially selected based on recommendations from NGOs. The network of interviewees was expanded during the study by asking each interviewed individual and organization if they could recommend other relevant actors they thought should be interviewed. A full contact list of the organizations interviewed is included in Appendix B.

2 Results of study

2.1 Results of rider interviews

The following presents the critical results from wheelchair rider interviews, and explains the issues the data demonstrate. The full compilation of data from the assessment is included in Appendix C. In all, 71 disabled people were interviewed in the assessment. In this section the terms "wheelchair" and "tricycle" are both used to describe types of mobility aids. Common examples of these machines are shown in Figure 2.1.

A) Wheelchair **B) Tricycle**

Figure 2.1 Common mobility aids

2.1.1 Causes of disability

Figure 2.2 shows the distribution of disability causes for the interviewees. Polio was the most common disability observed, at 38% of the interview population. Most polio survivors interviewed contracted the virus early in life.

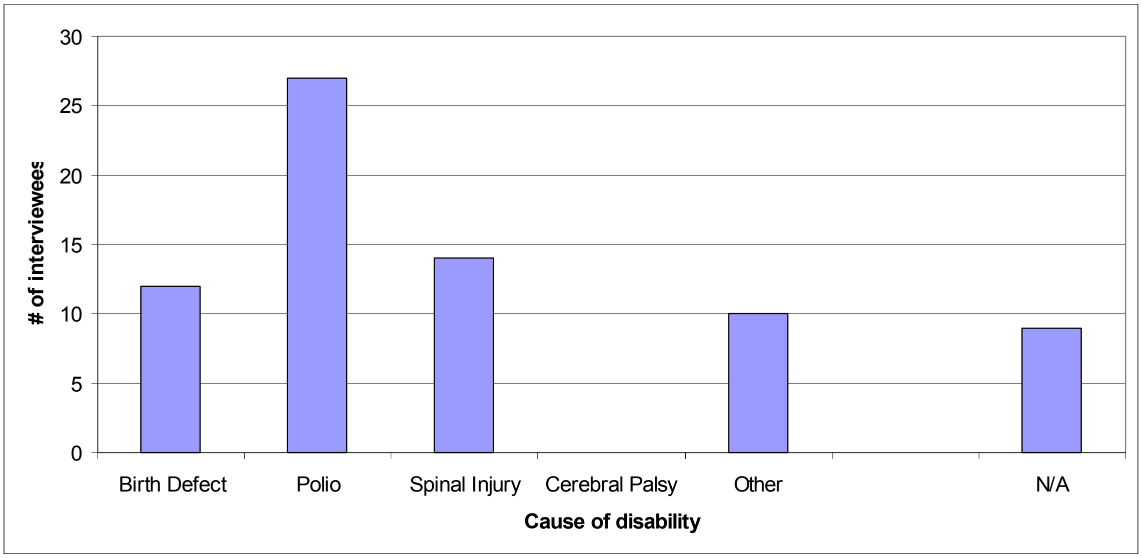


Figure 2.2 Distribution of interviewee disabilities

It is important to note that only people who were available or visible to the Investigator were interviewed. Survivors of birth defects and polio, who made up 54% of people interviewed, had been disabled for nearly their whole life. In comparison to the spinally injured, who became disabled typically later in life (~20 years old), birth defect and polio survivors had their entire life to acclimate to being disabled. Thus, the people who were able to work or beg on the street were more accessible for interviews, and make up a larger portion of the interviewees. Of these people most were survivors of birth defects or polio, and had been able to acclimate to their disability by being able to crawl or ride a mobility aid.

2.1.2 Pre-wheelchair mobility

As a result of the majority of interviewees becoming disabled early in life with a birth defect or polio, most had to resort to crawling as a means of mobility before obtaining a wheelchair or tricycle. This trend is clearly seen in Figure 2.3, with 49% of the interviewees crawling before obtaining their current mobility aid.

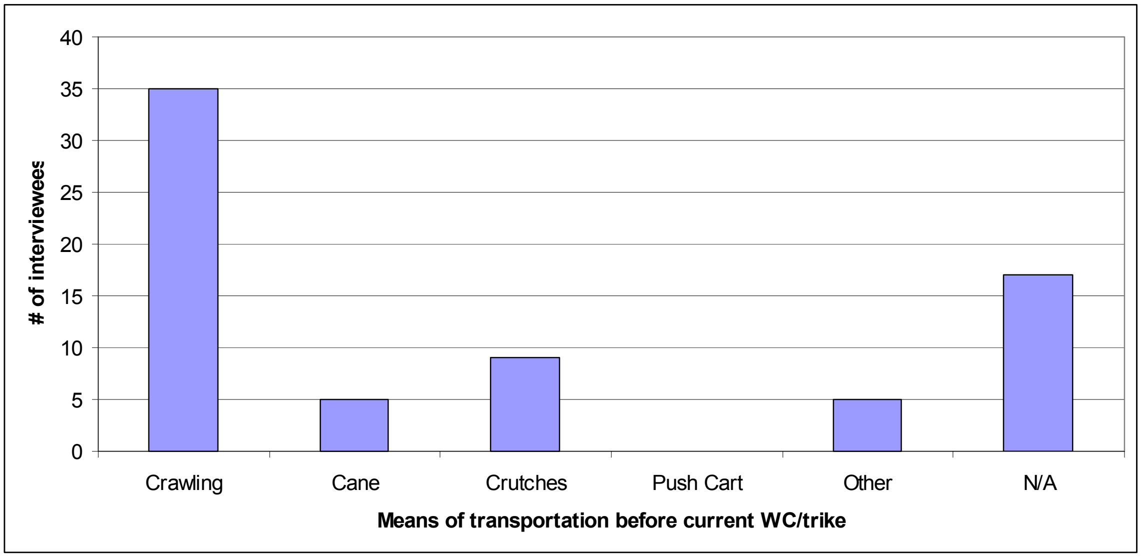


Figure 2.3 Travel before current mobility aid

Figure 2.4 demonstrates just how long most people must wait before receiving a mobility aid. The average interviewee age of obtaining a first wheelchair or tricycle was 22 years old. As a result, most people who went to school or had a job before the age of 22 were forced to crawl as a means of travel, while others were simply unable to attend school or obtain a job because of distance.

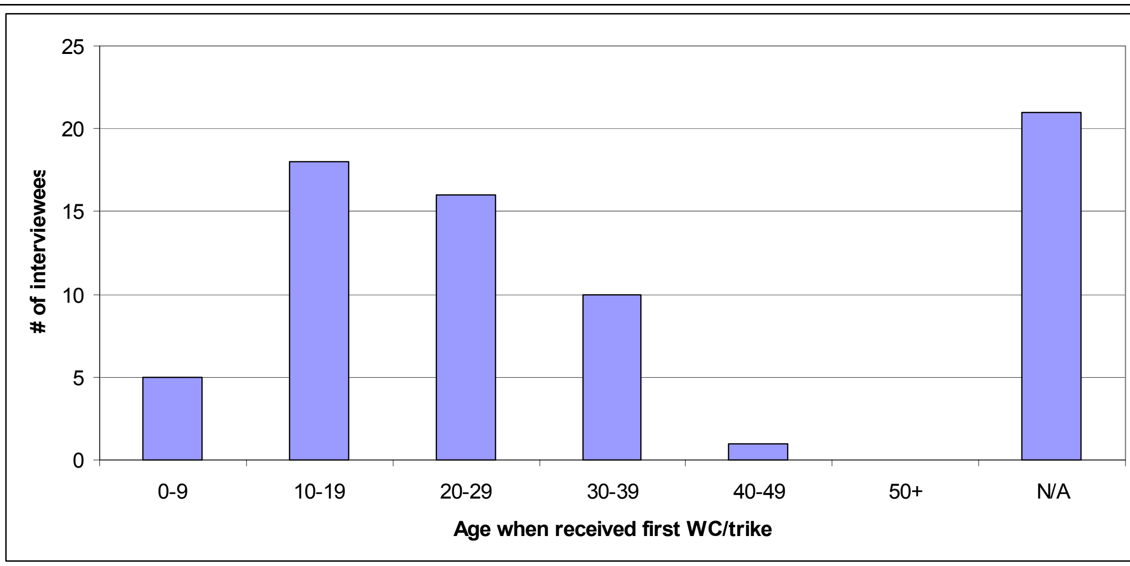


Figure 2.4 Age when first mobility aid obtained

2.1.3 Mobility aid usage after obtaining wheelchair or tricycle

Figure 2.5 and Figure 2.6 show important trends in the type of mobility aid individuals choose. Most of the interviewees needed to travel multiple kilometers per day, with 36% traveling more than 5km. For long distances, a tricycle requires much less power than a wheelchair. As a result, tricycles were observed to be more popular than wheelchairs. Although Figure 2.6 shows only slightly more tricycle users than wheelchair users, it is important to note that the Investigator had to make a concerted effort to find wheelchair users, but had to forgo many interviews with tricycle users. On the street, it was much more common to see a tricycle user. Wheelchair riders were only interviewed in hospitals, schools, and rehabilitation centers – places that required only hundreds of meters of movement per day. During the duration of the assessment, not a single wheelchair rider was seen outside of an independent facility or organization.

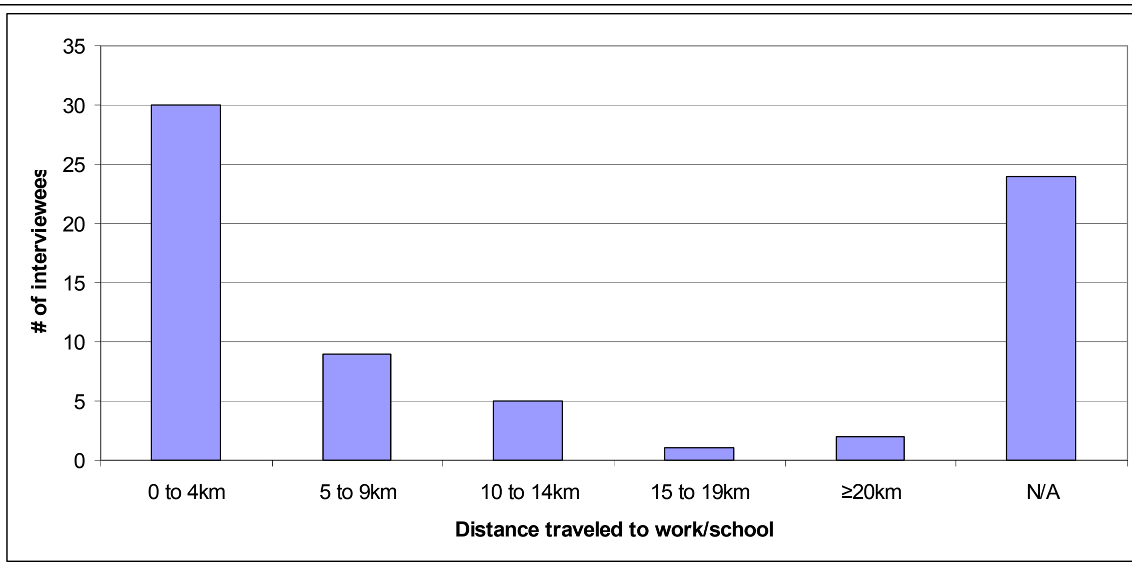


Figure 2.5 Daily travel distance of interviewees

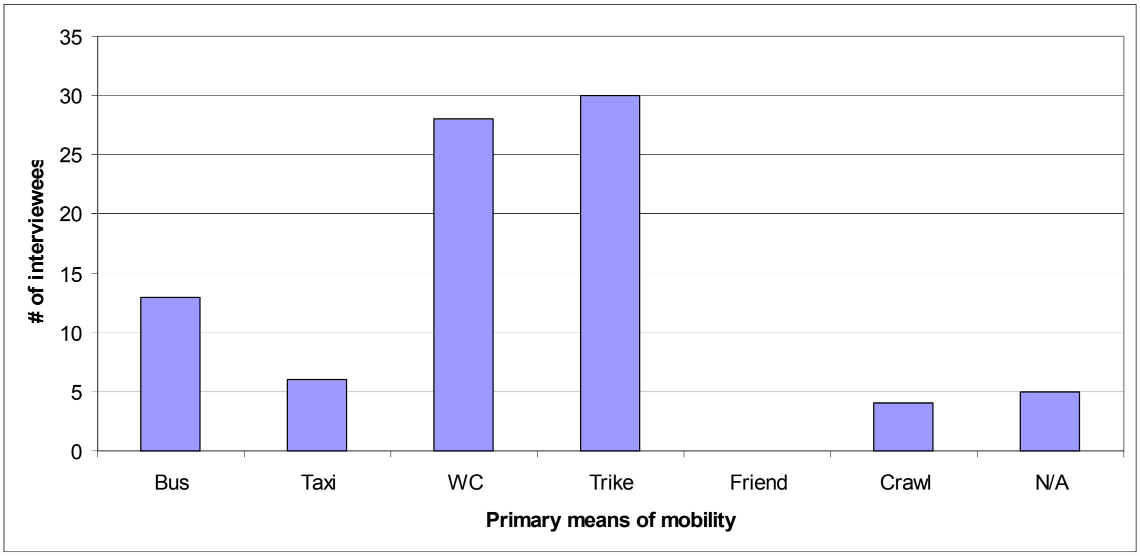


Figure 2.6 Means of transportation used

The preference of tricycles by the Tanzanian disabled can be further explained by comparing Figure 2.5 and Figure 2.6 with Figure 2.3 and Figure 2.4. Figure 2.4 shows that most of the people interviewed did not get a mobility aid until later in life (average age of 22), and Figure 2.3 shows many had been forced to crawl small distances. As a result, there is a greater need for many disabled to travel long distances, such as going from home to work. Since many of the interviewees were capable of crawling short distances, they were willing to forgo the short-range mobility offered by a wheelchair for the multiple-kilometer capabilities of a tricycle. Furthermore, the local busses are rarely equipped for or permit disabled people to ride, forcing them to rely only on themselves to travel long distances.

2.1.4 Wheelchair or tricycle purchasing ability

One major problem observed during the assessment was the inability of many people to purchase their own mobility aid. Figure 2.7 shows the distribution of income of the interviewees. The average monthly income is $49US. This is twice Tanzania's national average income of $24 per month.[6] This discrepancy can be attributed to the following factors: 1) People with jobs were easier to find and interview; 2) Most of the interviews were conducted in urban areas, where there are more formal and informal incomegenerating opportunities and higher average incomes; 3) Only 35% of the national population is urbanized.[7]

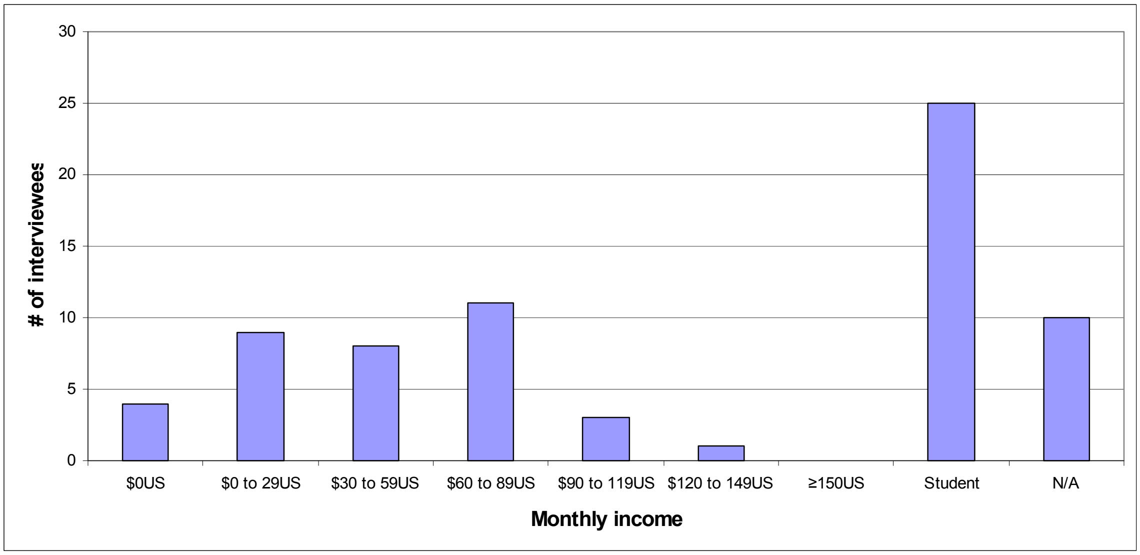


Figure 2.7 Income of interviewees

Figure 2.8 shows the large price gap between the cost of a new mobility aid and what users can afford. The majority of people interviewed, 67%, had wheelchairs or tricycles that cost between $100US and $200US, but 90% of the people who answered the question said they could only contribute $0US to $50US for a new chair or tricycle. This leaves approximately a $100US gap between what people can afford and what mobility aids cost. The majority of interviewees, 78%, did not contribute any money towards their current mobility aid. Figure 2.9 demonstrates how dependent disabled people are on contributions from others to purchase a wheelchair or tricycle. Only 14% of those interviewed were able to purchase their own mobility aid.

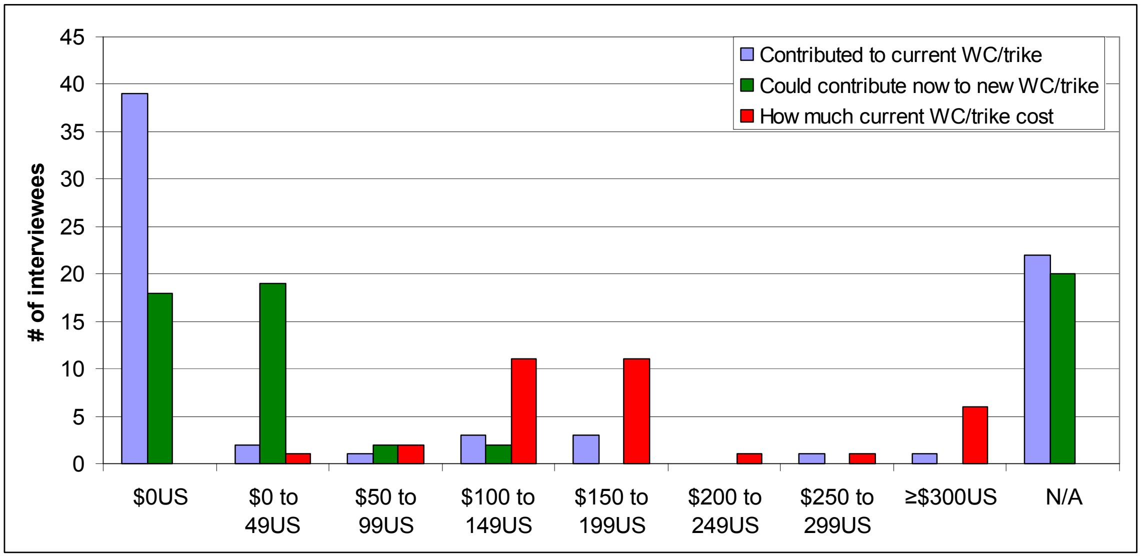


Figure 2.8 Price gap between wheelchair/trike cost and what user can afford

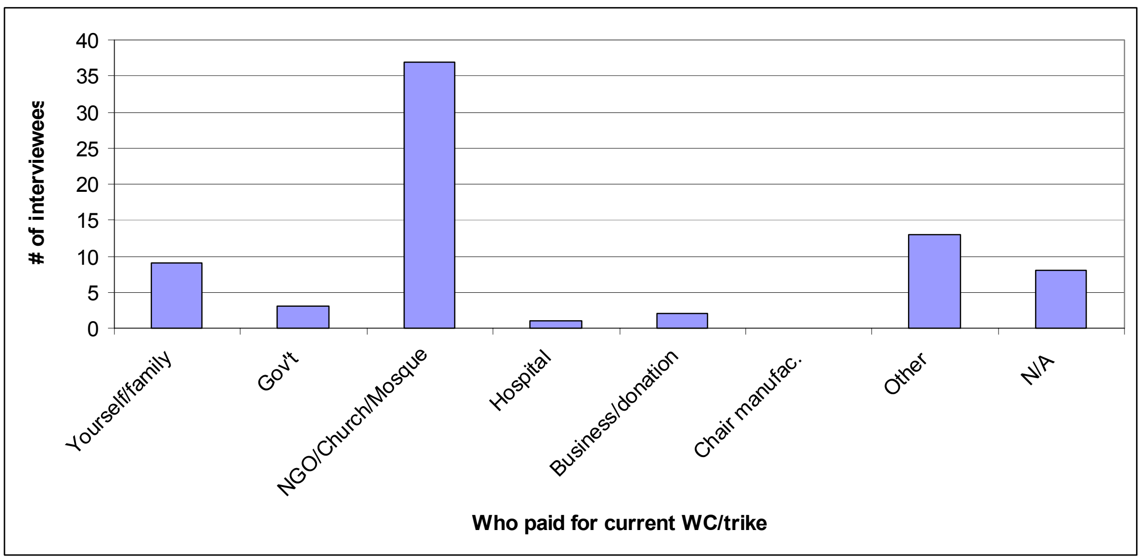


Figure 2.9 Sources of funds for current mobility aid

2.1.5 Locations of wheelchair repair

Bicycle shops were the most common location of wheelchair and tricycle repair reported during the assessment, as shown in Figure 2.10. In the category of "Other," 14 of the 17 responses were from children at the Salvation Army Rehabilitation Center who get their chairs repaired at the on-site workshop. The majority of those children said they have their chairs repaired at bicycle shops when they are at home. Part availability was a serious issue in how repairable chairs were. The most common complaint about foreign chairs was that spare parts are not available. Tricycles are easily repaired at bicycle shops because they are primarily built from bicycle parts.

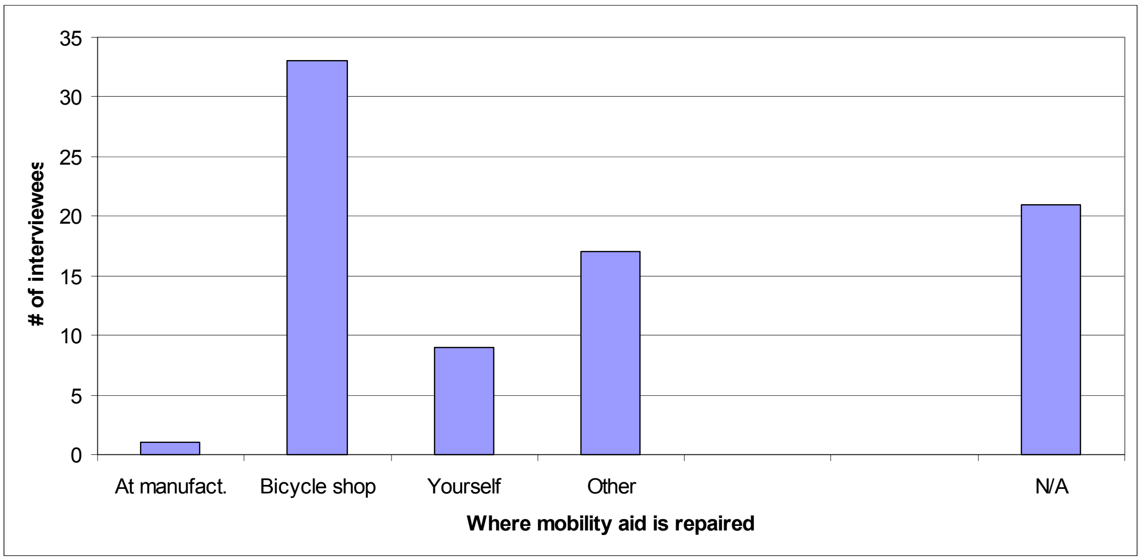


Figure 2.10 Distribution of mobility aid repair locations

2.1.6 Types of wheelchair being used

As mentioned previously, tricycles were much more common than wheelchairs. The variety of tricycles observed reflected both the desire of users and the market opportunities of many local manufacturers. They types of tricycles used by interviewees are displayed in Figure 2.11 and Figure 2.12. It is important to note that the locally made tricycles are made primarily from bicycle components. Manufacturing of the tricycle will be fully discussed in section 2.2.

Figure 2.11 Locally made tricycles

Figure 2.12 Imported tricycles

Figure 2.13 and Figure 2.14 show the types of wheelchairs that were used by interviewees. Imported wheelchairs were much more common, with 73% of wheelchair riders using a chair made abroad. The only people found using Tanzania-made wheelchairs as their primary mobility aid are the two men in Figure 2.13. The majority of imported chairs observed came from the Wheelchair Foundation, which has given thousands of chairs to Tanzania over the past decade. Further information on the Wheelchair foundation is included in section 2.3.

Figure 2.13 locally made wheelchairs

A) Expensive

B) Low-cost

Figure 2.14 Imported wheelchairs

2.1.7 Key points made by interviewees

The following are some statements made by interviewees and the location where they were made. These statements were chosen to be included in this report because they reflect important issues raised by many of the interviewees.

- **Yombo Rehab Center:** William - Prefers a tricycle over a wheelchair because he can go farther with a tricycle, can drive alone, and in a wheelchair you need someone to push you.

- **Salvation Army:** All people asked (7) said they would like to have a tricycle, but would prefer a wheelchair over a tricycle because they can go to the toilet and travel to class at school.

- **Usa River Rehab Center:** Anna - She was hidden at home before having a wheelchair. It is hard to get spare parts for her chair from the Wheelchair Foundation. Her wheels are meant for smooth surfaces and not good on rough ground.

- **Mnazi Moja:** Peter Amosi – He can't put his tricycle on the bus.

- **DAGE:** The most common disfunction that interviewees experienced with their chairs was popped tires.

- **YDDF:** Salum - Says tricycle (Blue with wooden sides in Figure 2.12) is uncomfortable because he is unable to relax as a result of the back of the seat. Can't compare her chair with DAGE chair because with DAGE you can carry a big load on it and it is faster. The pedals on her tricycle are too close to the chest and mouth, which is dangerous for an accident.

- **Wonder Welders:** Kombo - "The tricycle is my legs. I cannot differentiate it from my legs. I don't use it in the house or work. Yes, I would like one for work and travel. Be nice to have a portable wheelchair that can fold for bus. This would be better than a tricycle. Most of us live far away from work and have to wake up early. If they had a foldable chair they would take the bus."

2.1.8 Summary of wheelchair rider interview data

The following summarizes the important information covered in this section.

- Tricycles are much more common and popular than wheelchairs. The majority of interviewees spent much of their life crawling, and did not receive their first mobility aid until their 20's. Because most busses don't allow disabled people to ride, and most people need to travel multiple kilometers in a day, a tricycle is a more sensible choice for long-distance travel, with crawling used for short-distances.

- Most people cannot afford to buy their own mobility aid, and rely on NGOs or other organizations for help. For people to have the ability to purchase their own mobility aids, efforts must be made to decrease the gap between income and wheelchair/tricycle cost.

- The majority of wheelchairs that are used are imported, the most common of which are from the Wheelchair Foundation.

- Most people rely on bicycle shops to repair their wheelchairs or tricycles. This works for tricycles, as they are composed mostly of bicycle parts. Bicycle shops have difficulty repairing foreign wheelchairs because spare parts are unavailable.

After seeing the preference of tricycles over wheelchairs by many of the interviewees, the Investigator thought of an impromptu question to ask during interviews: "What do you think of the idea of using a conventional wheelchair with a tricycle attachment?" A tricycle attachment is a hand pedal-powered device that affixes to a standard wheelchair. For long distances, the rider can use the attachment, and then remove it to travel short distances. A wheelchair with a tricycle attachment would allow the user to have the short-range mobility of a standard wheelchair with the long-distance freedom of a tricycle.

The response to the tricycle attachment idea was overwhelming. Nineteen out of 20 people formally asked said they thought an attachment would be the best mobility solution. People liked the idea because the wheelchair could be used in their home, at work, and to go to the bathroom. It could be folded and put on a bus for long trips. If a local bus driver did not allow wheelchair users, the rider could use the attachment to travel multiple kilometers, and then remove it at the destination to use their wheelchair.

2.2 Results of manufacturer interviews

This section presents the results from interviews with wheelchair and tricycle manufacturers. The contact information for each manufacturer can be found in Appendix B.

2.2.1 Products of manufacturers

Table 2.1 reports the wheelchairs and tricycles being produced by the Tanzanian manufactures interviewed during the assessment. Note that the purpose of the table is to display products, not each manufacturer; some manufacturers are not included, and others that produce the same product are combined.

Table 2.1 Wheelchairs and tricycles currently produced in Tanzania

Product	Factory	Description	Price
	Palray	**1)** Sold throughout TZ, Congo and Zambia **2)** 15-20 trikes and 15-20 WCs/ month **3)** Trikes: 24, 26, 28" frames. WC one size	$150US for trike, $90 for hospital WC
 	Usa River welding and fabrication workshop	**1)** 2 seat sizes for trike, one for WC **2)** Only made 2 WCs **3)** Trike only weighs 20kg. Palray's weighs 48kg	$150US for trike, $250US per WC
	DAGE	**1)** Sell 20 trikes/ month **2)** Tried making Whirlwind WC, in past, but failed	$160 to $300US for trike
 	Jaffery	**1)** Makes 50-60 trikes per year, 100 WCs **2)** One size for trike and WC **3)** Has made off-road wheelchair	$135US for trike (sells at cost), $220 for WC
	KCMC Wheelchair Workshop and Mobility Care	**1)** Produce WTTC designs **2)** Target produce 10 WCs per month **3)** Chairs fit to riders	$230US 3-wheel $250US kids $250US 4-wheel
 	UWZ Wheelchair Workshop	**1)** UWZ itself buys %50 of chairs **2)** Produce 4 trikes or WCs per month **3)** Chair based on WWI design **4)** Size WCs to riders	$140US for WC, $120US for trike

2.2.2 Price comparison

Table 2.1 shows the large price difference between wheelchairs and tricycles. The tricycles cost approximately $100US less than the wheelchairs. This might contribute to the greater popularity of tricycles over wheelchairs in Tanzania. In order to be competitive, the workshops run by WTTC graduates, KCMC and Mobility Care, should lower their prices to more competitive levels. Suggestions of how to do this are included later in this section and in Chapter 3. Price reduction should be possible, considering the UWZ workshop is able to sell a chair that is very similar to the WTTC 4-wheeler for just $140US.

Upon inspection of tricycle manufacturing facilities, the following factors were observed that contribute to lower production costs.

- **Minimized individual part production:** Palray produces only the frames of the tricycles they build, shown in Figure 2.15. All other parts are purchased. This practice greatly decreases production time and the variety of tasks workers are required to complete.

- **Maximum usage of bicycle parts:** Other than the frames, all the other parts in a Palray chair are from bicycles. Many of the parts are produced in China, and are purchased at a much lower cost than manufacturing them in Africa. Reducing fabrication and primarily assembling the tricycles hugely reduces production time, which further lowers cost.

- **Assembly line production:** All of the tricycle shops used some sort of assembly line, with dedicated people in charge of one or only a few production steps. The work is more repetitive, but time for switching setups and tasks is reduced.

- **Incentive-based payment:** Jaffery uses commission based salary, and competition between employees producing the same parts. The competition motivates employees to out-produce their competitor, thus increasing production rates.

Figure 2.15 Frame production at Palray

2.2.3 Observed weak points in design

The following describes observed weak points in the mechanical design of wheelchairs and tricycles. Many solutions to these problems are suggested in Chapter 3.

2.2.3.1 Axle strength

The axles used in the WTTC 4-wheeler are too weak. There are many loading conditions where the axle might bend. One of these conditions is represented by Figure 2.16, where the full load of one person is exerted on one of the rear wheels while the chair is tipping. A situation where this loading condition could happen is when a friend is pushing a wheelchair rider off a curb on the rear wheels, one wheel drops before the other, and the full load of the person is exerted on that one wheel. The dimensions in Figure 2.16 were taken from a WTTC 4-wheeler, and the load is a 670N (150lbs) person.

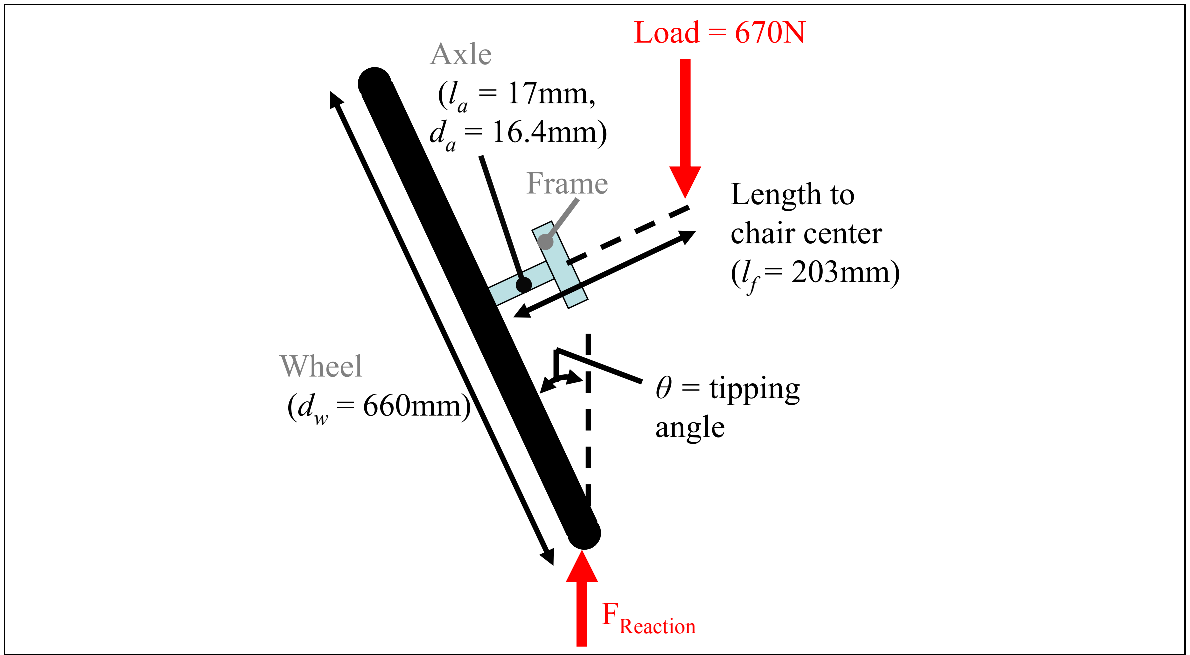


Figure 2.16 Tipping of WTTC 4-wheeler

Bending stress is defined by Equation 2.1, where I is the second moment of area of the bent member, and y is the distance from the neutral axis.

$$\sigma = \frac{My}{I} \qquad \textbf{2.1}$$

The highest bending stress will occur where the axle joins the frame. The moment at that point is found by summing the moments caused by the reaction force and using the lengths in Figure 2.16, shown Equation 2.2.

$$M = F_R \sin\theta(330mm) - F_R \cos\theta(52mm) \qquad \textbf{2.2}$$

Combining Equations 2.1 and 2.2 with the applied Load gives Equation 2.3, which gives the bending stress in the axle as a function of tipping angle.

$$\sigma = \frac{1.55N}{mm^3}\left[\sin\theta(330mm) - \cos\theta(52mm)\right] \qquad \textbf{2.3}$$

The tip over point of the chair is at 31deg, where the center of mass is vertically over the reaction point of the wheel and the ground. If the frame is made of mild steel, with a yield stress of 330N/mm^2, the bending stress at that angle is 59% of the yield strength of the steel. This is in a static loading condition. If a chair were to drop off a curb only a few inches, the shock load could be multiple times greater than the static load, thus the yield stress could easily be reached. Or if a person was sitting in the lap of the rider, increasing the load on the chair, the stress in the axle could be closer to yield. Also, considering the highest stress is occurring at a point where the axle is welded to the frame, weakening of the material from the weldment should be factored in.

In any case, the axle is far too weak. Considering the rough operating conditions in the developing world and that people who are susceptible to injury are riding in these machines, the axles should be designed to take stresses of approximately 5 to 10X the load in Figure 2.16. To give a comparison, elevators which carry people are usually designed to withstand 7 to 11X the posted maximum load.

2.2.3.2 Bottom tube on WTTC 4-wheeler

The instructor at the WTTC reported that a common failure in the WTTC 4-wheeler was cracking of the weldment on the bottom tube next to the X-brace. A repaired picture of this area of the frame is shown in Figure 2.17. The X-brace exerts a large torque on this tube, so a stress analysis should be done on its design. The tube diameter might have to be increased, or the stop for the X-tube bushing might have to be joined through another process than welding or brazing, as to not weaken the frame material.

Figure 2.17 Cracked weldment on bottom tube of WTTC 4-wheeler

2.2.3.2 Weakness of center pivot on X-brace

A number of workshops reported that the holes that hold the bolt for the center pivot of the X-brace would quickly wear out and open up, decreasing the rigidity of the brace. The fatiguing of the brace hole is the result of high torques being exerted on the pivot pin when the chair is on 3 wheels, such as when rolling over rough ground. A 4-wheeled chair is probably not the best solution for very bumpy operating environments, because unless the frame has a lot of compliance or slack in the joints, only 3 wheels will be touching the ground at any one time. Also, when the chair is on 3 wheels, it is much less stable and comfortable for the rider.

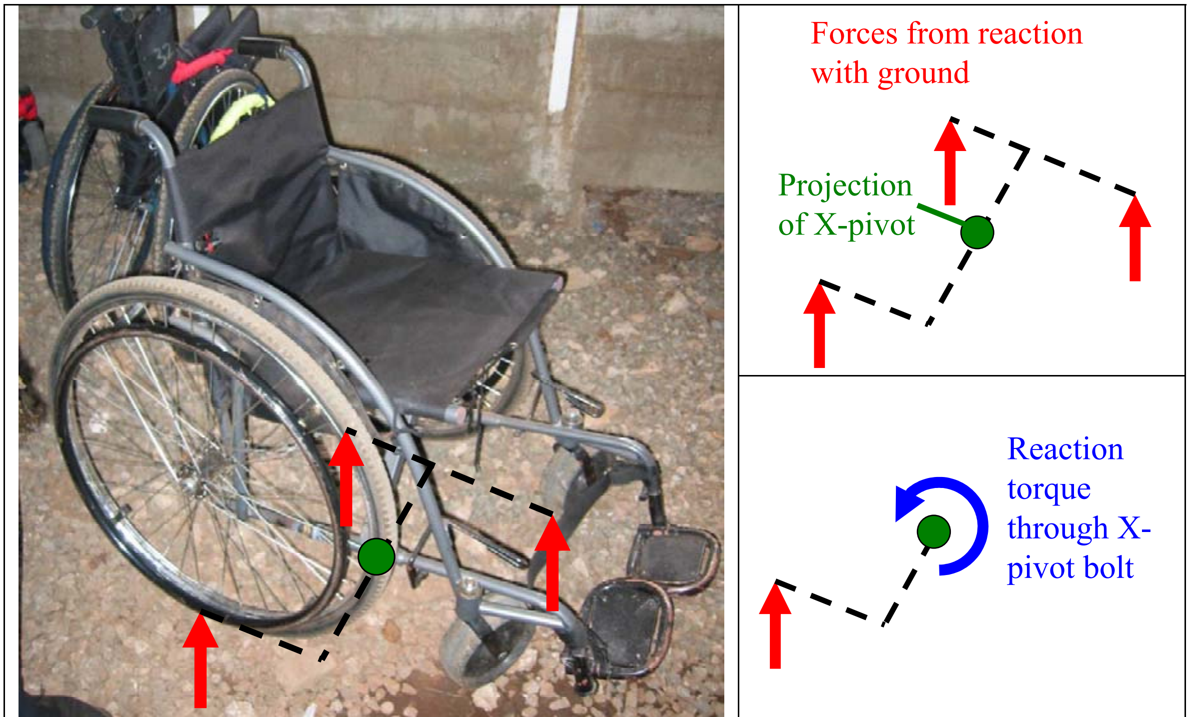


Figure 2.18 Projection of moments in X-brace of WTTC 4-wheeler

To fix this problem, a bushing could be welded into each of the legs of the X-brace to increase the contact area with the pivot bold. Or, two X-braces could be fitted to the chair; one near the front of the seat and one near the back. This configuration would better counteract the torque generated by going on 3 wheels.

Probably the best solution is a chair with 3 wheels in a triangular configuration. Mobility Care says in its brochure “3 wheels, ideal for African roads.” This configuration would always be kinematically constrained with the ground. Kinematically constrained means the chair is touching the ground with exactly the number of points to define the plane it is sitting on. Three points are required to define a plane. In the WTTC manuals, this concept is referred to as the milk stool principle; a milk stool has 3 legs, and is kinematically constrained with the plane of the floor, so it never rocks back and forth.

2.2.3.4 Frame weakness in Tanzania-made tricycles

Many of the tricycles observed had bent frames, or had frames that had been bent in the past and since repaired. The frame weakness is the result of the second moment of area being too low in the center of the frame. This problem was observed in the Palray, Jaffery, and DAGE frames. A bucked frame and corresponding moment being generated within the frame are shown in Figure 2.19. From Equation 2.1, the bending stress is proportional to the moment in the material, thus the highest stress will occur at the point of highest moment. In the tricycle frames, the highest moment occurs in the center of the frame. The bending stress is also proportional to the inverse of the second moment of area. Thus the frame stress can be reduced by increasing the second moment of area. This can be done by using larger diameter tubing, or by adding supports to counteract frame bending.

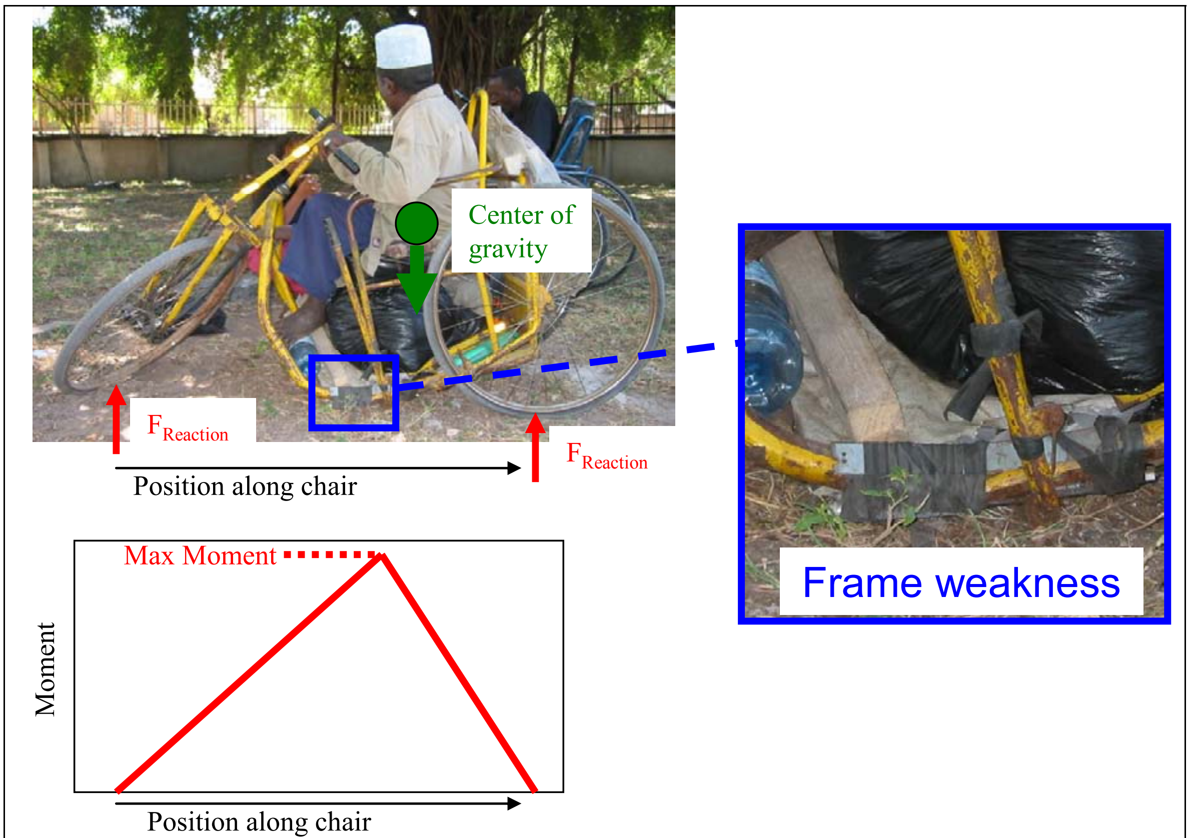
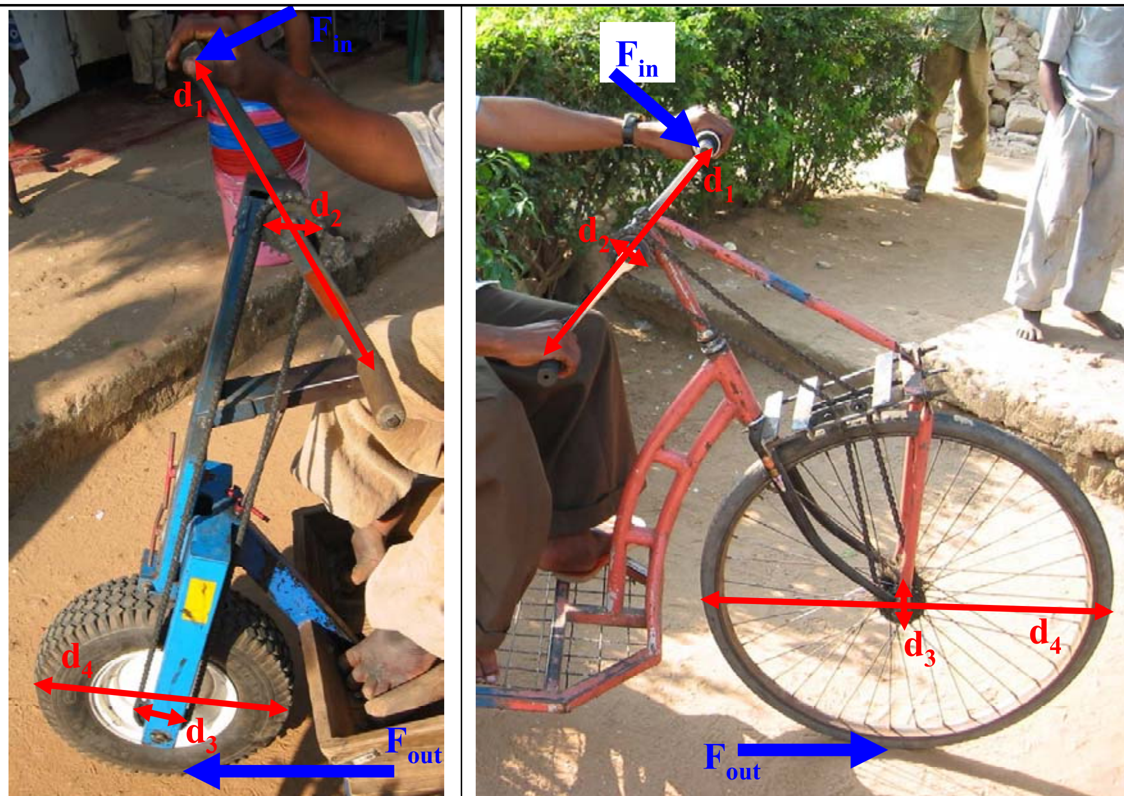


Figure 2.19 Buckled frame of a Palray tricycle and corresponding bending moment

The second moment of area can be thought of as the amount of material that acts as a lever arm to counteract the bending of a member. If the member is a tube, the bending will occur about a line that is perpendicular to and intersects the axis of the tube. By making the tube diameter bigger in diameter, the tube material above and below the bending line is farther away, thus having more leverage to counteract the bending. I-beams used in buildings are designed around this principle. By making the beam in the shape of an "I", most of the material is placed on the top and bottom horizontal parts of the "I", far away from the line of bending.

2.2.3.5 Gearing in tricycles

Many of the tricycle riders observed while traveling seemed to be working much harder than necessary. After riding a tricycle and experiencing the difficulties first hand, it was clear that the gear ratio was not well matched for human force and power capabilities. Figure 2.20 show the gear ratio schematics of two tricycle designs, with each critical element characterized by its diameter. Figure 2.20A is a Canadian tricycle that is very easy to ride, and Figure 2.20B is a DAGE tricycle that takes much more force to power.



A) Tricycle made in Canada | B) DAGE Tricycle

Figure 2.20 Gear ratios of tricycles

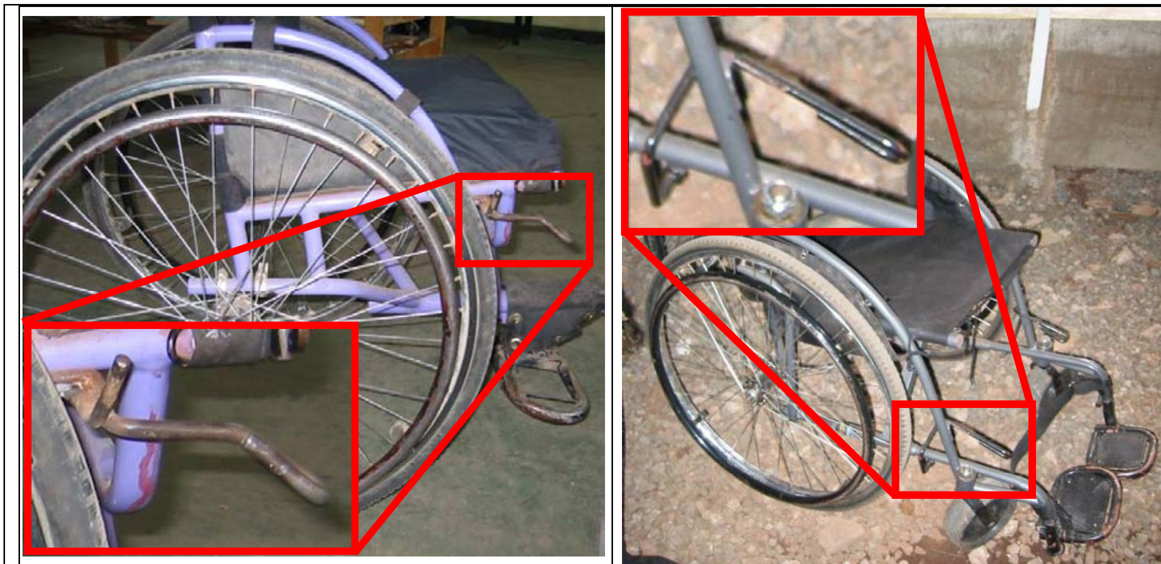
Using the dimensions of Figure 2.20, the relationship between the force required by the user, F_{in}, and the output force used to move the chair, F_{out}, is expressed in Equation 2.4.

$$F_{out} = F_{in} \frac{d_1}{d_2} \frac{d_3}{d_4} \qquad \textbf{2.4}$$

From rough comparisons between the two pictures in Figure 2.20, the DAGE tricycle produces a much lower force out than the Canada tricycle. This causes the user to work much harder. To solve this problem the power and corresponding force a human can output with their arms should be researched or experimentally calculated. Then using variations of Equation 2.4 that account for road slope, ground friction, and gear inefficiency, the optimum gear ratio should be determined to maximize traveling velocity while not overexerting the user.

2.2.3.6 Brake placement and design

All of the WTTC graduates interviewed preferred the break location and design of the WTTC 3-wheeler, shown in Figure 2.21A, over the WTTC 4-wheeler brake, shown in Figure 2.21B. They said the 4-wheeler brake is too low, and it takes too much force to disengage because the contact has to get pressed farther into the tired to unlatch the handle from the stop. A simple solution is to adapt the 3-wheeler brake onto the 4-wheeler.

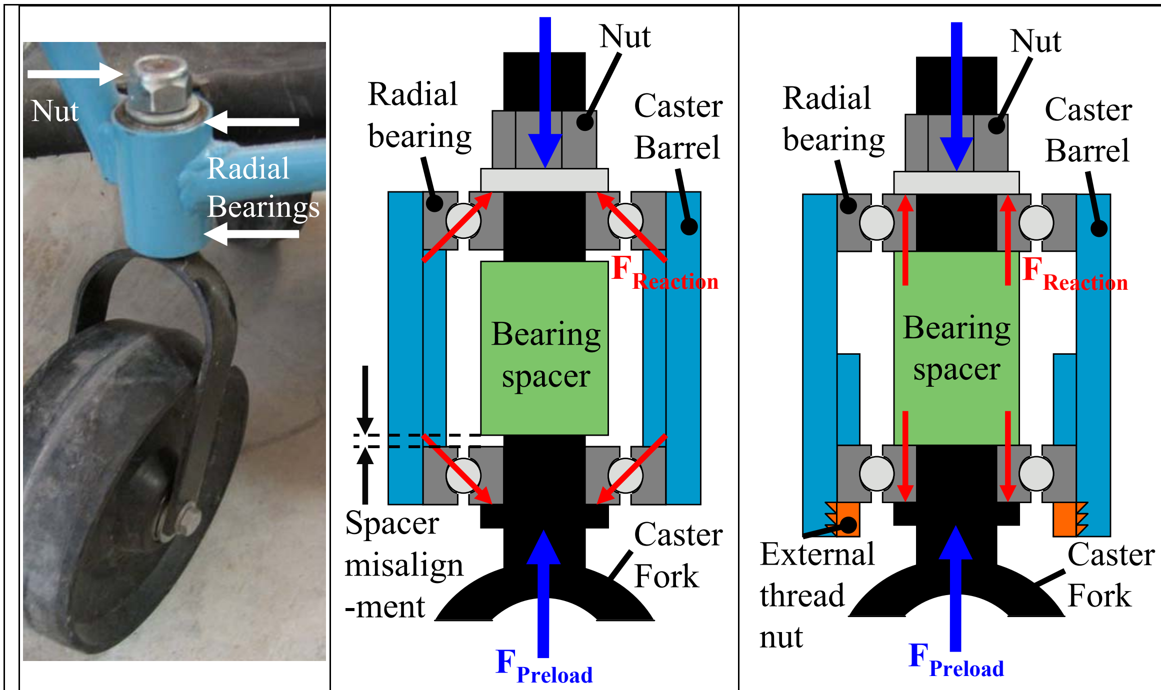


A) WTTC 3-wheeler **B) WTTC 4-wheeler**

Figure 2.21 Brake location and design of Tanzania wheelchairs

2.2.3.7 Bearing mounting

All of the radial bearings in the WTTC designs are mounted in an over-constrained configuration. Over-constraining the bearings can greatly decrease their life by inducing much high stresses on the balls and races through misalignment. Figure 2.22 shows the current over-constrained design, and an alternate exactly constrained design for the caster bearings.



A) Current mounting configuration of castor bearing | **B) Current mounting configuration, over constrained** | **C) Exactly constrained mounting configuration**

Figure 2.22 Mounting of caster bearings

The bearings in Figure 2.22A are over-constrained because they are supposed to be located on too many surfaces; the outer race is supposed to butt up against the shoulder on the caster barrel, while the inner race is supposed to butt up against the bearing spacer. One can imagine that if the bearing spacer is a little too short, the inner race will not hit the spacer. The preload force from the nut will then be transferred through the bearing balls into the out race, as shown in Figure 2.22A. If the nut is tightened further, increasing the preload force, the balls and races will become compressed and sheared, easily damaging the bearings. Radial bearings are not designed to take high axial loads. If the bearing spacer is too long, then the bearings would be under-constrained, and could slide up and down.

Figure 2.22B shows a mounting configuration that exactly constrains the bearings. Increased tightening of the nut will not damage the bearings, because the preload force will be transferred through the external faces of the inner races, which are designed to be compressed. The bearings will not slide up and down because the external thread nut will exactly position the bottom bearing, and the upper bearing will be clamped between the spacer and the nut.

It is important to note that any configuration of radial bearings used in the castor swivel is a bad configuration, as radial bearings are not meant to support axial loads. Loading them axially can greatly shorten their life. The proper configuration would be to use either two angular contact bearings, like what is in bicycle hubs, or one radial and one thrust bearing, like what is sometimes used in bicycle stems.

2.2.4 Other information from manufacturers

The following information from manufacturer interviews is important and worthy of reporting.

- The WTTC 4-wheeler is being marketed primarily as a hospital chair. This is disconcerting because it is intended to be also used in rough environments. The function of the 4-wheeler should be re-evaluated, and possibly re-designed to best suit its role.

- UWZ no longer wants to run the workshop because they don’t have the manpower to supervise it. They want to give the shop either to the technicians or sell it to another company. UWZ has enough money to buy enough chairs and keep the workshop in business. Every year they incorporate money into their budget for need based, cost shared WCs to be purchased.

- DAGE very much wants to produce WCs. They have tried in the past, but failed because of lack of materials and training. Their supervisor, Mr. Henry Chacha, would very much like to study at the WTTC and start a wheelchair workshop at DAGE. He already meets the WTTC requirements, being fluent in English and obtaining high marks in the required subjects.

- Mobility Care makes their own hubs at $2US per hub. UWZ outsources their hubs, and buys them for $1.20US each. WTTC graduates might consider outsourcing to: 1) lower cost, and 2) avoid the overhead of buying a lathe for hub manufacturing.

- The idea of a wheelchair with tricycle attachment was discussed at Mobility Care, and the technicians thought it was a great idea. They thought it would most appropriately suit the needs of Tanzanian wheelchair users of any other design.

2.2.4 Summary from manufacturer interviews

The following is a summary of the ideas derived from manufacturer interviews.

- Decrease prices of WTTC wheelchairs to compete with tricycles. Right now there is a $100US price difference between WTTC chairs and Tanzanian tricycles. UWZ is able to produce wheelchairs for just $140US.

- Use of bicycle parts and outsourcing lowers prices and also makes the wheelchairs and tricycles easier to repair by bicycle workshops.

- The strength of many wheelchair and tricycle designs should be re-calculated to determine if they can sustain stresses caused by environments in developing countries.

- Bearings should be correctly mounted, as to not shorten their life.

- A wheelchair with tricycle attachment should be investigated as a possible product for WTTC graduates to produce.

- Both DAGE and UWZ wheelchair workshops are suitable locations for a WTTC graduate. The UWZ workshop could become independent from UWZ under the supervision of a WTTC graduate, and DAGE has a qualified WTTC candidate in Mr. Henry Chacha.

2.3 Results of advocacy group interviews

This section summarizes the information gained from advocacy group interviews. The contact information of each interviewed organization is included in Appendix B.

2.3.1 Organizations purchasing wheelchairs

Most of the organizations interviewed do not purchase wheelchairs or tricycles, and instead rely on donations. Those that do buy chairs are reported below, along with details about how many WCs they buy and how much the organizations spend on chairs and tricycles.

- Tanzania Disabled Person's Movement (TDPM) – can spend up to $350US
- Sibusiso – Gets grants for full cost of Tanzania-made wheelchairs up to $250US
- UWZ - $12,000 budgeted for wheelchair purchasing in 2004. They subsidize the cost for members.
- IPP – Bought and donated 55 tricycles from Palray in 2004
- CCBRT – Buys one Tanzanian-made wheelchair for $250US every month

2.3.2 The Wheelchair Foundation

The US-based NGO Wheelchair Foundation (WF)[8] is by far the largest donator of wheelchairs in Tanzania. Below are the interviewed organizations to or through which it has donated wheelchairs and the number of wheelchairs distributed.

- Tanzania Big Game Safaris (TBGS) – WF has given 6,720 to TBGS over the last 6 years. TBGS distributes the chairs in villages within its hunting land, as part of the company's community development work required by the national government of hunting companies.
- EOTF – Has given away approximately 2,000 WF chairs since 2003
- Monduli Rehabilitation Center – Currently has 3 WF chairs
- Usa River Rehabilitation Center – Has received a handful over the past few years
- Salvation Army Rehabilitation Center - Gives away about 10 wheelchairs per year, but not all are from WF.

Although the thought behind free wheelchairs is noble, the WC chairs sometimes are not appropriate mobility aids. The chairs are not fitted to users, and thus do not always provide the appropriate support and comfort. Poorly fitted chairs can actually do harm to the user, by failing to support the torso or causing pressure sores. Even if the chair is suitable, there are no replacement parts available, so if the chair breaks it can immediately become useless or dangerous.

Interviewees also suggested that WF chairs are distributed randomly without careful selection of recipients based on an assessment of their disabilities and needs. TBGS said WF will give a chair to anyone who seems to need one – a loose requirement that may include people who are crawling on the ground to people who may walk with a crutch. TBGS admitted they get so many chairs every year that after the first few hundred have been distributed, it is very difficult to find genuinely disabled people to whom they can give them. EOTF said they use a similar distribution method. Ideally, TBGS could also give chairs to hospitals and rehabilitation centers that need them instead of wasting so many.

The price of a WF chair is $150US. Half of that price is paid by the WF, and the other half is paid by donors. If wheelchairs being produced in Tanzania could be sold at or near $150US, they could better compete with the WF. It may even be possible to convince the WF to buy local chairs and support local businesses and the disabled. Either way, the price of WF chairs is further evidence that Tanzanian-made wheelchair prices must decrease.

2.3.3 Mobility aids in urban areas

Wheelchairs and tricycles in cities have to meet many of the same requirements as mobility aids used in rural areas. The terrain in cities is often hilly, and the roads are most often unpaved. As was mentioned in Section 2.1, many disabled people must travel long distances between home and work. This is often the case in cities, because the residential areas are often far from the business district.

Another factor raised by urban NGOs is that disabled people are rarely allowed to ride public busses. Even with a folding wheelchair, the conductors often won't let them on because of the extra room they require inside, and the time they take to get on and off. There has been increasing legislative pressure to reverse these policies, but it is not yet enforced. As a result, disabled people usually have to depend on their own power to travel long distances, which helps explain why tricycles are more popular than wheelchairs.

2.3.4 Mobility aids in rural areas

Some important issues with wheelchairs in rural areas were raised by NGOs. These points are summarized below.

- Monduli Rehabilitation Center: The woman who was interviewed criticized the WF and said wheelchairs should not be given out like candy. She feels, because the village terrain is so rough, people should be encouraged to walk with crutches or braces, and WCs should be a last resort.

- Sibusiso: All Sibusiso wheelchairs are purchased from Mobility Care. Sibusiso have never been denied a wheelchair grant from the Dutch foundation Liliana funds. They said it is easy to get people to donate money for wheelchairs. All that is needed is a picture and a story – with those, charities in industrialized countries will gladly donate $250US. Sibusiso made a strong point about the WF: People are scared not to give out all the chairs that are donated. They feel obligated to do so, or chairs will not be donated in the future.

- All organizations interviewed agreed that they did not like the imported wheelchairs because replacement parts can not be obtained. They all thought using bicycle parts was a good alternative because even in the most remote villages, there is usually a bicycle repair shop.

- Wheelchairs in the rural areas are not distributed well at all. While TBGS distributes thousands to people who might not need them, organizations like A Beacon for the Disabled, Usa River, and Monduli desperately need them.

2.3.5 Summary of advocacy group interviews

Important information from the interviews with wheelchair advocacy groups is summarized below.

- Few organizations are able to purchase chairs, but international NGOs like Lilana funds are willing to subsidize purchases.
- WF is a huge donator in Tanzania, but it does not use appropriate technology, fitting, or distribution practices.
- The cost of wheelchairs produced in country has to be reduced if they are to compete with WF chairs.
- Bicycle parts can be and are effectively used in rural areas because most villages have bicycle repair capability.

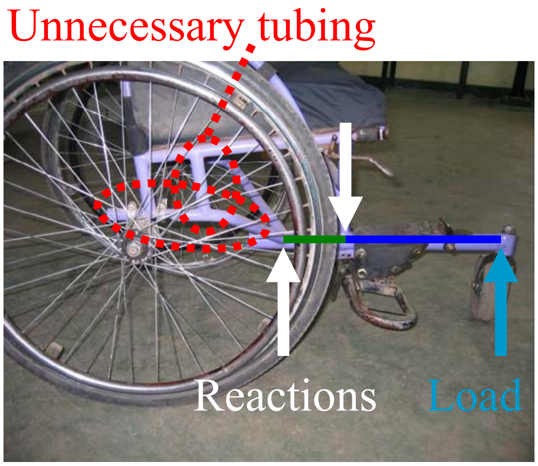
2.4 Compilation of available materials/components

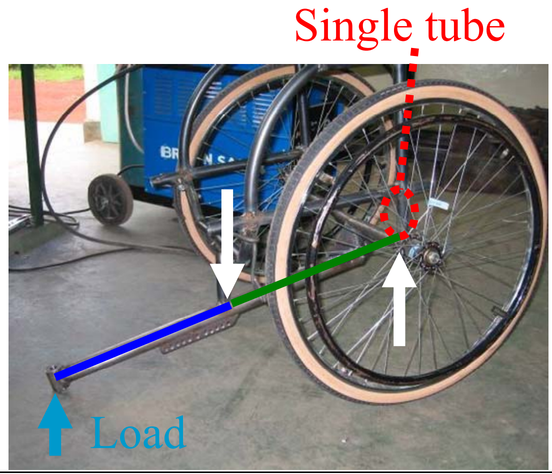
A wide selection of steel and bicycle components is available in Tanzania. Doshi Hardware, Ltd was visited, and their product line is included in Appendix D. They carry a full range of steel stock. Burhani Cycle Mart provides almost every bicycle component available, including frame joints to be brazed. Burhani's selection and prices are include in Appendix E. Contact information for both Doshi and Burhani can be found in Appendix B.

2.5 Results from review of WTTC course material

The most significant problem observed in the WTTC literature is students do not learn the tools to engineer, but only to produce the exact designs taught in the course. The design approach that is taught comes from more of an industrial/product design point-of-view rather than from mechanical design. The students learn very few analytical skills, which is disconcerting considering that people vulnerable to injury are using the devices they construct. The only validation of engineering ideas that is introduced is through iterative testing. The manuals spend too much time on technical drawing, and far too little on the behavior of materials, how to make things strong, and proper ways to constrain components. There are also some engineering mistakes, such as over-constraining the bearings in the wheels and castors. The complete set of review comments is included in Appendix F.

It is important not only to teach the students how to make wheelchairs, but to also design them. Engineering knowledge leads to improved designs, and also allows the technicians to adapt to changing conditions, material availability, and customers. The technicians at Mobility Care and the KCMC workshop all expressed a deep desire to learn more about mechanical engineering. Some manufacturers were able to improve their designs just by being clever and inventive. For example, the technicians at the UWZ workshop designed stronger, reinforced X-pivot holes. They also found a way to use bicycle hubs for bearings in the front caster wheels. The technicians at Mobility Care changed the frame of the WTTC 3-wheeler get rid of 4 pieces of unnecessary tubing and also balance the internal reaction forces. Their improved frame design is shown in Figure 2.23.





A) Old 3-wheeler design	B) New Mobility Care 3-wheeler

Figure 2.23 Improved 3-wheeler frame design by technitions at Mobilty Care

3 Recommendations

This chapter introduces recommendations for improving wheelchair technology in Tanzania.

3.1 Technological improvements for current wheelchairs

The following design suggestions are intended for application to current Tanzanian wheelchairs.

3.1.1 Replace all bearings with bicycle components

The idea of using bicycle components in wheelchairs appears multiple times in this report. Bicycle bearings can improve wheelchairs in the following ways.

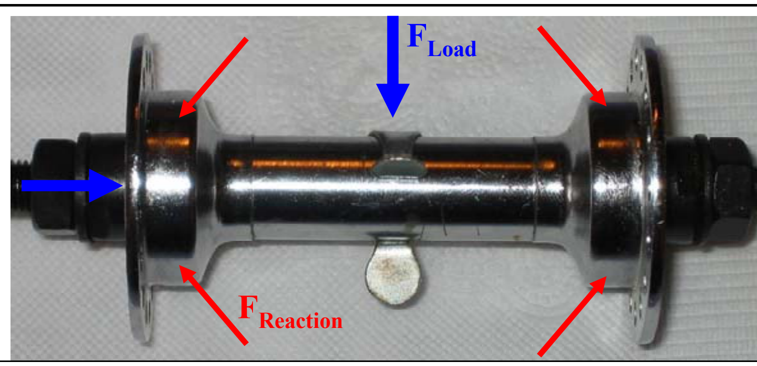
- Bicycle parts are available in almost every part of the country, even in remote villages.
- Wheelchairs made with bicycle bearings would be repairable at any bike shop. Most people already rely on bike shops to repair their wheelchairs and tricycles.
- Bicycle bearings are up to four times less expensive than conventional bearings.
- Bicycle bearings can be completely disassembled, as shown in Figure 3.1. This means the bearings can be easily cleaned and re-greased, prolonging their life.
- Angular contact bearings, which are the most common type of bearings found in bicycles, are more appropriate for wheelchair use than radial contact bearings. Wheelchair bearings are usually subjected to radial and axial loads, which angular contact bearings are designed to support, as shown in Figure 3.2.

A) Stem bearing components

B) Hub components (bearing balls not shown)

Figure 3.1 Bicycle components dissassembled

A) View of bearing balls and race



B) Bearing contact angles and reactions to loading forces

Figure 3.2 Angular contact bearings in a bicycle hub

3.1.2 Designs to incorporate bicycle bearings into wheelchairs

This section presents designs that replace every conventional radial bearing with bicycle components in current WTTC wheelchairs.

3.1.2.1 Rear wheel bearings

The first design, shown in Figure 3.3, replaces the wheel bearings with bicycle stem cup bearings. This design uses has the bearings mounted within the frame instead of inside the hubs, with the axle and hub fabricated as one part. This hub configuration was chosen for the following reasons:

- The axle diameter can be made stronger and lighter. This design has a hollow axle of 25.4mm in diameter and 2.65mm wall thickness – a pipe size readily available through Doshi. Because of the increase second moment of area, the axle in this design is 225% stronger and 14% lighter than the WTTC 4-wheeler axle.
- The axle/hub can be fabricated out of one tube and two discs.
- The frame sides can be symmetric and made in the same jig. The significance of this manufacturing step is explored in a later section.
- The wheel and axle can be easily removed for cleaning.

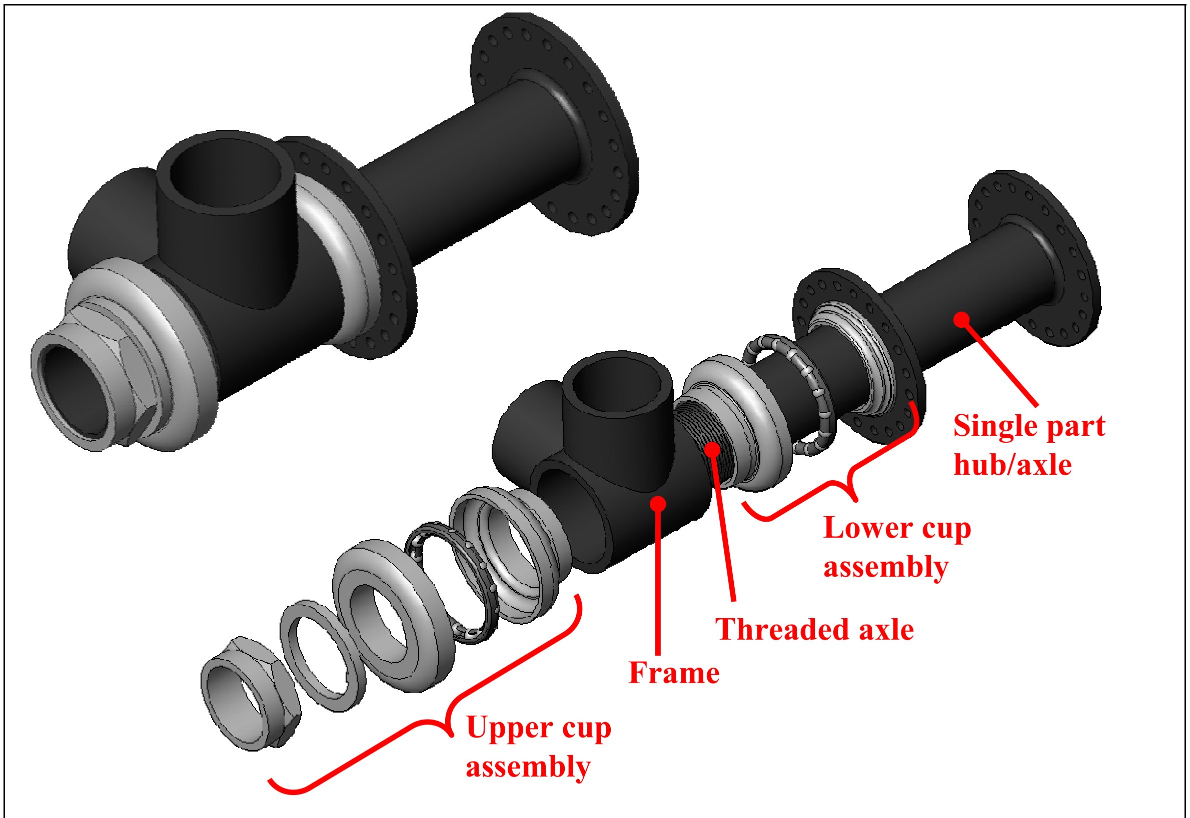


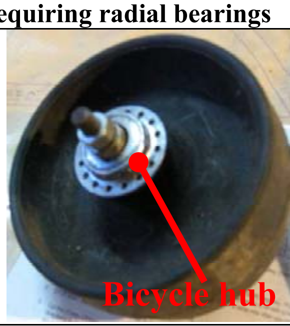
Figure 3.3 Single part hub/axle and bearing configuration, assembled and exploded view

Life calculations were performed on this design using the method presented in Shigley.[9] Even with the high loading and rough conditions of an African operating environment, these bearings should last 10 years with a 99% confidence of no failure.

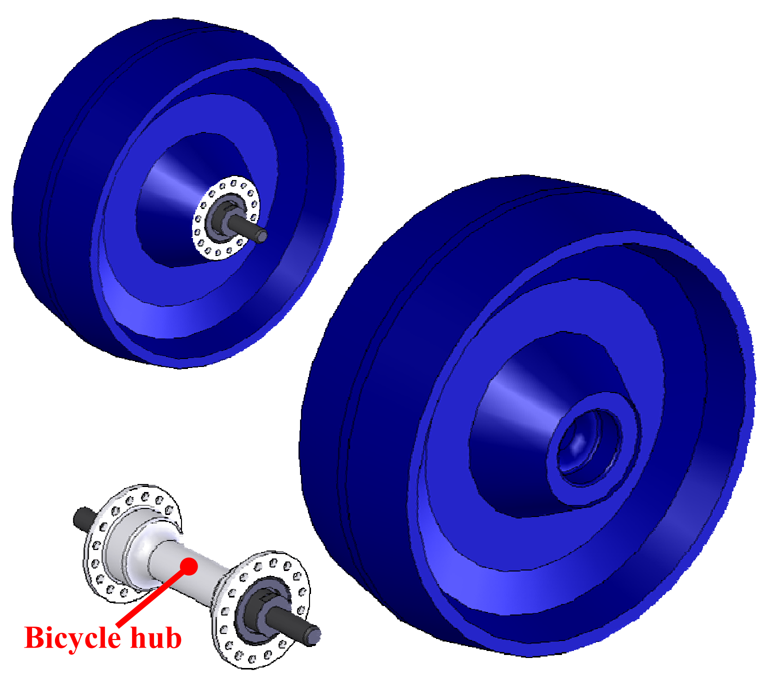
3.1.2.2 Front caster wheel bearings

The next design replaces the radial bearings in the front caster wheels with bicycle hubs. The front casters are made from cast rubber, as shown in Figure 3.4. One method of putting the hub inside the tire is by pressing it in. This method is already used by the UWZ wheelchair workshop, as shown in Figure 3.4B. Bicycle hubs are made by pressing two steel flanges onto a steel center tube. UWZ assembles its casters by pressing off one flange, putting the other flange and attached tube through the tire, and then pressing the flange back on.

A) Standard caster requiring radial bearings



B) UWZ caster with pressed-in bicycle hub



C) Assembled and exploded view of bicycle hub cast into caster tire rubber

Figure 3.4 Caster tires currently in use and in a proposed simplified design

An alternate method of assembling the casters would be to cast the tire rubber directly onto the bicycle hub, as shown in Figure 3.4C. Currently, the tires being used by WTTC graduates, shown in Figure 3.4A, are made from two different rubbers: a stiff rubber for the bearing shoulders and a compliant rubber for the outer tire. If the tire was cast directly around the bicycle hub, only the complaint rubber would be required. This would reduce the casting process by one step.

3.1.2.3 Front caster swivel bearings

The final design replaces the radial bearings in the caster swivels with a bicycle hub, as shown in Figure 3.5. Using the a hub for a swivel bearing is an idea solution, as the castor swivel suffers much more from combined axial and radial loads than the wheel bearings. Since the hub is made of steel, it can be welded directly to the frame tubes. The common front hubs in Tanzania, made by Phoenix Bicycles, have a threaded rod long enough to extend into the caster fork. The dimensions in Figure 3.5 are accurate for the wheel, hub, and frame tubing size used in the WTTC 4-wheeler.

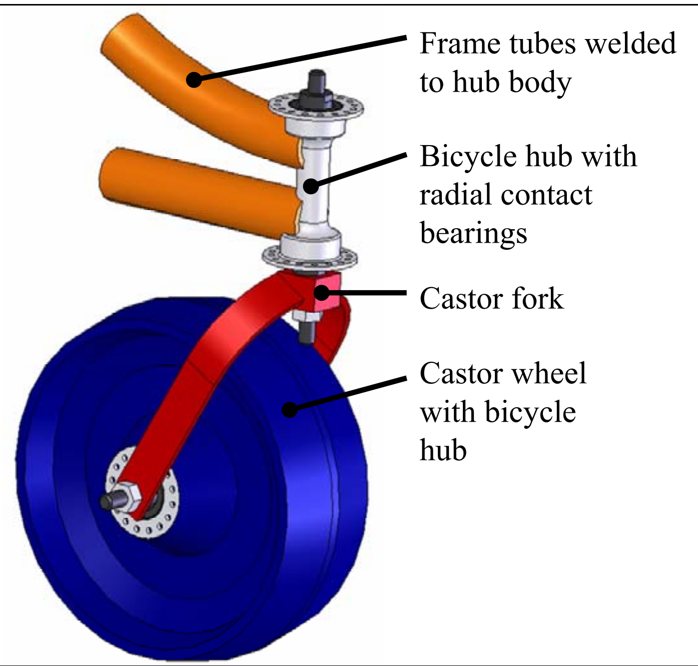


Figure 3.5 Caster swivel bearing made from bicycle hub welded to frame tubes

Another option for replacing the swivel bearings could be to use a plastic bushing. PVC bushings have been successfully used by KickStart (formerly Approtec) for the foot levers in their Super Moneymaker irrigation pump.[10]

3.1.3 Financial benefits from bicycle parts

Table 3.1 compares the cost of the radial bearings currently used in the WTTC 4-wheeler and the proposed bicycle component substitutions. The prices for radial bearings were obtained from Mobility Care, and the bicycle part prices are from Appendix E. Replacing bearings with bicycle components saves $23US on the wheelchair cost, which is almost 10% of the overall price.

Table 3.1 Cost comparison between currently used bearings and bicycle component replacments

	Bearings currently used / Cost per wheelchair	**Bicycle part replacement / Cost per wheelchair**
Function		
Front wheel bearings	4 X Type 6202 ZZ radial, sealed ball bearings / 4 X $2.50	2 X Bicycle front hubs / 2 X $1.00
Front wheel castor swivel bearings	4 X Type 6202 ZZ radial, sealed ball bearings / 4 X $2.50	2 X Bicycle front hubs / 2 X $1.00
Rear wheel bearings	4 X Type 6202 ZZ radial, sealed ball bearings / 4 X $2.50	2 X Bicycle stem bearing cup sets / 2 X $2.50
	Total costs per wheelchair	
	$30	**$7**

3.1.4 Improved manufacturing techniques

A number of lean manufacturing techniques can be applied to the production of WTTC wheelchairs. The following suggestions could help improve manufacturing efficiency and lower cost.

- **Design wheelchair frames with symmetric sides:** Modifying the frame design of the WTTC 4-wheeler to have symmetric sides could greatly reduce production time. Only one jug would be required for the whole chair, which would avoid setup time between left and right jigs. The rear axle design in Figure 3.3 would compliment a symmetric frame, as the required unsymmetrical features, the axles, are part of the hubs. Wheel camber would have to be forgone to make the frame parts symmetric, but this may be a tolerable sacrifice. A study on cost decrease vs. wheelchair performance should be conducted to see the importance of camber. It is important to note that all the tubing in a symmetric frame would have to lie in one plane. Planar tubing might make the frame assembly easier, as all the pieces could be laid on one surface.

- **Outsource some manufacturing processes:** WTTC graduates are valuable because they have the skills to properly fit people to wheelchairs. Some of the manufacturing tasks they are required to do, like machining and painting, might better be accomplished at a lower cost and higher quality through outsourcing. If a piece of equipment like a lathe, which is priced at $4000US in the WTTC business plan, is only used to make hubs, it might be much more economical to have t produced elsewhere. UWZ buys its hubs, custom made, for $1.20US each. At that price, and producing 10 wheelchairs per month, it would take almost 14 years to justify the cost of a lathe. Another example is having the frames and hand rims powder coated. By outsourcing painting, the product could be improved by having a tougher, powder coated finish, the technicians would have more time to attend customers, and the startup cost of buying a compressor and paint sprayer heads would be avoided. The two outsourcing practices presented here are only ideas, and should be substantiated with a cost-benefit analysis.

- **Remove non-load bearing components:** The WTTC wheelchairs have some components in their frame that do not serve the function of carrying weight. One example was the unnecessary tubing in Figure 2.23. Another example is the seat-stop tube in Figure 3.6. By removing such components or designing other components to serve multiple functions, there will be less material in the chair, reducing weight and cost. A possible solution to the tube in Figure 3.6 is to bend a curve into the back tube to hit the seat. Or, a small loop of tubing could be added onto the back tube.

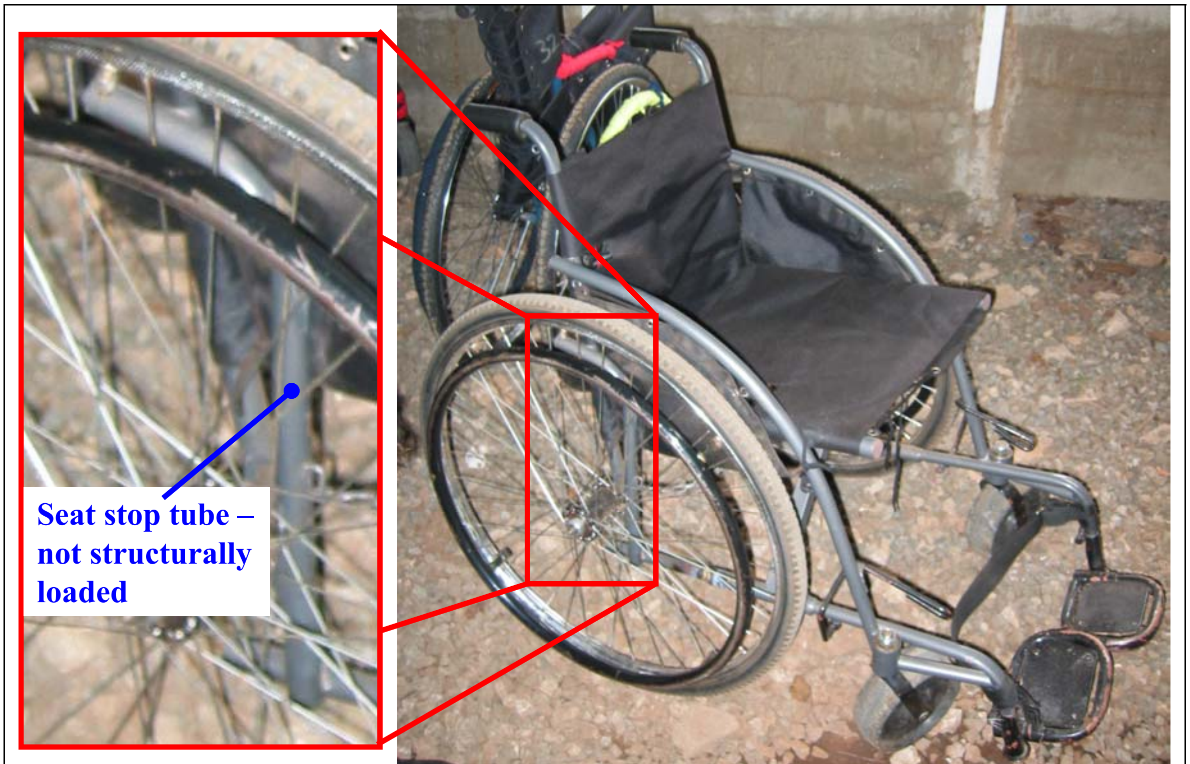


Figure 3.6 Seat stop tube that is not load bearing and contributes to excess material

3.1.5 Importance of price reduction

Reducing the cost of Tanzanian wheelchairs is critical to making them more desirable, accessible, and affordable. Currently, the WTTC chairs cannot compete with tricycles in terms of price, and they are much more expensive than donated foreign chairs. If the price is lowered, then the WTTC chairs might be able to compete with the chairs distributed by the Wheelchair Foundation. A price of $150US is surely possible, considering that is the UWZ workshop wheelchair price. If the WTTC chairs can be priced similarly to Wheelchair Foundation chairs, then a partnership might be formed where local manufacturers are supported. WF most likely has a contract with their

Chinese manufacture. If both the Tanzanian and Chinese chairs cost the same, possibly both could be used: the Chinese chairs in hospitals and the WTTC chairs by private individuals.

3.1.6 Other engineering suggestions

The following are miscellaneous suggestions of how to improve mobility aid technology.

- Perform a complete engineering analysis on the current WTTC designs to insure they are strong enough and properly designed for rough operating environments.

- Redesign tricycle frames with increase second moment of area at the points of highest stress. This issue was discussed further in Chapter 2.

- Optimize the gear trains in tricycles to better match human power capabilities. This issue was discussed fully in Chapter 2.

- Investigate alternative mounting arrangements of the hand pedals on tricycles. Figure 3.7 shows the prototype developed between the Investigator and DAGE for a new aligned hand crank design. The design is to prevent the front wheel from steering side to side during pedaling. The design also allows the rider to use larger muscle groups in the abdomen and back. The technicians at DAGE liked the crank arrangement very much, and though it performed better than the current opposed crank arm design.

Figure 3.7 Prototyping new aligned crank configuration at DAGE

3.2 Future Tanzanian mobility aids

Inspecting the feedback from current wheelchair and tricycle users, and assessing the pitfalls of current mobility aid technology, a next-generation wheelchair should be designed in the future. The most versatile type of mobility aid would be a wheelchair with a tricycle attachment. As was reported in Chapter 2, the tricycle attachment concept was very popular with interviewees and wheelchair workshops. This new type of wheelchair would meet the short and long distance mobility needs of Tanzania's disabled. To fully serve wheelchair users, the following features should be included in the next-generation African wheelchair with tricycle attachment.

- **3-wheeled:** A three-wheeled design is best suited for the rough terrain of both urban and rural Tanzania. Three wheels are always in contact and kinematically constrained with the ground, making the chair very stable on rough surfaces.

- **Foldable frame:** For trips longer than what is possible with the tricycle attachment, the wheelchair must be stowable on busses. Allowing the frame to fold gives the chair the functionality of a 3-wheeler with the packability of a folding 4-wheeler.

- **Stowable tricycle attachment:** The wheelchair should have an area or fixture on which to stow the tricycle attachment. This area could possibly be on the back of the chair. The rider should have the option of keeping the tricycle attachment affixed to the chair, as there may be situations where leaving it alone might not be safe or feasible.

3.3 General recommendations for the WTTC course

The following recommendations might be used to improve the WTTC course.

- **More mechanical engineering theory in the WTTC curriculum:** Increased knowledge of mechanical design will allow students to make design improvements, accommodate their environment and available materials, and make customizations easier.

- **Re-evaluate the role of the 4-wheeler:** The WTTC graduates interviewed said the 4-wheeler is being sold primarily as a hospital wheelchair. Customers prefer the 3-wheeler for rough environments. If the 4-wheeler is going to be used as a hospital chair, maybe it can be produced at a lower cost by simplifying the design and decreasing the number of parts.

- **Investigate the possibility of a WTTC tricycle:** Tricycles are much more popular than wheelchairs in Tanzania. There might be a large market opportunity for WTTC graduates to produce tricycles.

3.4 Locations for future WTTC workshops

During interviews with workshops and advocacy groups, it became apparent that the following organizations are ideal for becoming WTTC workshops.

- **UWZ Wheelchair Workshop:** This workshop has been established for nearly 20 years, and has experienced technicians. It is in threat of going out of business or being sold to another company because UWZ does not have the manpower to supervise it. They would prefer to give the shop to the technicians instead of selling it. UWZ has the funds to purchase enough wheelchairs and tricycles from the shop annually to keep it in business. The shop is a perfect management opportunity for a WTTC graduate. In the meantime, Mobility Care said if funding is provided they would be happy to have the UWZ technicians apprentice at their shop.

- **DAGE Tricycle Workshop:** The manager of the DAGE workshop, Mr. Henry Chacha, is a perfect candidate for the WTTC. He is fluent in English, scored high marks in the required classes, and is passionate about learning more about wheelchair design. After completing study in the WTTC course, Henry could return to DAGE and expand it into a wheelchair workshop. DAGE already has the equipment, facility, and technicians needed to produce wheelchairs.

- **Tanzania Disabled Person's Movement (TDPM):** When interviewed, TDPM said they have the money and facilities to start a wheelchair workshop and sponsor someone to study in WTTC course. TDPM said they have many employees who meet the entrance requirements for the WTTC.

4 Future work

I would very much like to continue work on wheelchair technology in Tanzania. I feel the best way to improve technology on the large scale is to empower wheelchair manufactures by giving them more knowledge of mechanical design. I am proposing to write a new mechanical engineering manual for the WTTC course. This manual would focus on the fundamentals of mechanical design, specifically pertaining to wheelchair design. This manual would fill the void of mechanical engineering subject matter in the WTTC course content.

My plan for producing the manual is as follows: I could write the manual next summer, most likely on another MIT Public Service Center fellowship. The manual would be presented at the 2006 African Wheelchair Congress to be held in Arusha, Tanzania. At the Congress I would run a short course on mechanical design that is based on the manual. All the attendees would receive a free copy that they could bring home to their own workshops. The manual would then be taken to the WTTC and used as another course module.

MIT has offered me the opportunity to teach a seminar course in the spring of 2007 on wheelchair design in developing countries. This course would be the perfect medium to prototype a next generation wheelchair with tricycle attachment. MIT students could design and fabricate the wheelchair while collaborating with individuals from TATCOT and WWI. This course could be a unique opportunity to develop a wheelchair that fully meets the needs of Africa's disabled population by combining the experience of TATCOT and WWI in developing country wheelchair design with the technical capabilities of MIT students.

5 Accomplishments of the assessment

The following list summarizes the accomplishments of the assessment and this final report.

- Identified bicycle components to replace all radial bearings in current WTTC wheelchairs. Performed the calculations necessary to verify their use. The use of bicycle components is an appropriate technology because they can be easily cleaned and replace throughout Tanzania.
- Identified design problems in current wheelchairs and tricycles produced in Tanzania, and suggested viable engineering solutions.
- Identified manufacturing methods which can reduce the cost of the wheelchairs, including designing symmetric frames, using bicycle parts, outsourcing some tasks, and having all frame components load-bearing.
- Based on interview data, outlined functional requirements of second generation wheelchair with tricycle attachment.
- Proposed a manual on mechanical engineering for wheelchair design. This manual will educate technicians about mechanical concepts in order to improve their design capability.
- Proposed a seminar on wheelchair design, to be taught at MIT. The outcome of this course will be a prototype of a next-generation Africa wheelchair.
- Aided Emanuel Chitete of the Muhimbili workshop in re-opening communication with Motivation and eventually obtaining the necessary funds to start a workshop.
- Put the UWZ workshop in contact with TATCOT and the NGO Motivation, and they are currently exploring ways to make the shop independent and run by a WTTC graduate.
- Formed a contact list of practically all Wheelchair related organizations in Tanzania, which can be used in the future for such organizations to contact and use each other.
- Distributed safety equipment that was donated by MIT to wheelchair shops and the Wonder Welders.

- Helped DAGE prototype a new aligned crank arm arrangement, which they thought performed better than the current arrangement.
- Made design suggestions to DAGE about how to strengthen their frames with gussets and how to possibly add a motor to a tricycle.
- Suggested to the UWZ technicians how they can make better welds by grinding off the galvanizing from their frame pipes before welding.
- Put Michael Venance, a patient at Muhimbili Hospital, into contact with KASI so they could help him.
- Donated a eithernet cable to KASI.
- Bought new chain for Mama Neema, a woman who was interviewed in downtown Dar es Salaam.
- Gave Tanzania Big Game Safaris' and Sibusisso's contact info to Usa River to help them get chairs donated. Told Usa that TBGS has so many wheelchairs, they could probably give them some.

6 Summary

The purpose of this report was to gain insight into the factors that are preventing Tanzania's disabled from utilizing wheelchair technology. Three types of interviews were conducted during the assessment, one for each group involved with wheelchair technology: wheelchair and tricycle users; wheelchair and tricycle manufacturers; and advocacy groups for the disabled. The most critical points in the responses of each group are summarized below:

- **Wheelchair and tricycle users:** Tricycles are the preferred mobility aid because they offer long-distance travel capability at a lower price compared to wheelchairs. Most people rely on NGOs and other organizations to purchase mobility aids, and the majority of wheelchairs being used are imported. Bicycle shops are the most common place to get wheelchairs and tricycles repaired. 95% of individuals asked thought a wheelchair with a tricycle attachment would be the ideal solution for both short and long distance mobility.

- **Wheelchair manufacturers:** The WTTC wheelchairs cost $100US more than tricycles produced in Tanzania. The UWZ wheelchair workshop is able to make a wheelchair similar to the WTTC 4-wheeler and sell it for $140, which is $100US less than the WTTC workshops. Utilizing bicycle parts and outsourcing in production lowers prices. The current WTTC wheelchairs have design weaknesses and should be reviewed for strength and robustness.

- **Advocacy groups:** Few organizations can afford to buy chairs, but international donors like the Liliana fund are possible sponsors. The WF donates an immense number of wheelchairs annually, but without responsible distribution practices and full consideration of appropriate technology. Tanzanian wheelchairs should be priced to compete with the WF. Bicycle parts are appropriate to use in rural wheelchairs because they are easily replaced and cleaned.

The issues voiced by interviewees were treated as mechanical design problems. Appropriate design solutions are posed in this report. Designs are presented that replace all radial bearings in WTTC chairs with bicycle components, which are easily repaired and cleaned. The bicycle components also reduce the overall wheelchair price by nearly 10%. Lean manufacturing practices are recommended to reduce cost and production time. A next-generation wheelchair with tricycle attachment that can fully meet the needs of users is discussed. Finally, strategies for increasing wheelchair technicians' mechanical engineering knowledge to promote design improvement at the workshop level are introduced.

The information presented in this document is meant to aid TATCOT and WWI in planning strategies for future wheelchair technology improvements. Ideally this report will aid TATCOT in improving the WTTC course and WWI in designing improved wheelchairs in the future.

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Appendix A: Interview questions

Wheelchair User Questions

Site of Interview___________________

Date of Interview___________________

1 Background

1.1. Name:____________________________

1.2. Sex: ☐M ☐F

1.3. Date of birth (Age):______________________(_______)

1.4. Place of birth:______________________

1.5. Where do you live now: ☐Rural area ☐Urban area ☐ Other_____________

1.5.1. If rural, how far from nearest town/city:

☐0 to 5km ☐5 to 10km ☐10 to 15km ☐15 to 20km ☐ >20km

1.5.2. Name of city/town/village where you live:____________________

1.6. What is your primary means of transportation:

☐Bus ☐Taxi ☐Wheelchair ☐Friend ☐Crawl ☐ Other________

1.7. What are the types of surfaces on which you travel:

☐Paved ☐Dirt road/bumpy ☐Mountainous ☐Coastal/sandy/wet ☐Hot/sandy/rocky ☐Other____

1.8. Did you ever attend school: ☐Yes ☐No

1.8.1. Did your disability ever prevent you from attending school: ☐Yes ☐No

1.8.1.1. If yes, explain why:_______________________________________

1.8.2. What was the highest level of school you attended:

☐Primary ☐Secondary ☐College ☐University

2 Family life

2.1. Do you: ☐Own a home ☐Rent a home ☐Live for free in another's home ☐Live in a shelter ☐Live on street ☐ Other________________________

2.2. Do you live: ☐Alone ☐With family ☐With friends ☐ Other________

2.3. If you live with family, do you live with:

☐A wife ☐Children (how many_____) ☐Parents ☐Other relatives

3 Work/income

3.1. Do you have a job currently: ☐Yes ☐No

3.1.1. If yes, where do you work, since when:_____________________________

3.1.2. If no, have you ever had a job, doing what, when:____________________

3.2. What is your monthly income:

☐0US$ ☐0 to 50US$ ☐50 to 100US$ ☐100 to 150US$ ☐ >150US$

3.3. Does the government assist your income: ☐Yes ☐No

3.3.1. If yes, how much per month:_____________________________________

3.4. Do you make enough money to support yourself: ☐Yes ☐No

3.4.1. If no, explain____

3.5. Are you in dept/do you have to or had to borrow money: ☐Yes ☐No

3.5.1. If in dept, how much____

3.6. How far do you travel to work every day:

☐0 to 5km ☐5 to 10km ☐10 to 15km ☐15 to 20km ☐>20km

3.7. How do you travel to work

☐Dala dala ☐Taxi ☐Wheelchair ☐Friend ☐Crawl ☐ Other________

3.8. Before this job, what were you doing for work:____________________, ☐n/a

4 Your disability

4.1. What caused your disability:

☐Birth defect ☐Polio ☐Spinal injury ☐CP ☐ Other___________

4.2. When did you become disabled (at what age):______________________(____)

4.3. Before obtaining a wheelchair, how did you move around: ☐Crawling ☐Cane ☐Crutches ☐Push cart ☐Other_____________ ☐n/a

4.4. Is anyone else in your family disabled: ☐Yes ☐No

4.5. Do you require continued medical treatment for your disability: ☐Yes ☐No

4.5.1. If yes, explain:____

5 Obtaining wheelchair

5.1. Do you have a wheelchair: ☐Yes ☐No (If no, skip sections 5-7)

5.2. How/where did you get your chair:__________________________________

5.3. Was your chair locally manufactured in TZ: ☐Yes ☐No

5.4. Who made your chair:____

5.5. How much did it cost: ☐0US$ ☐0 to 50US$ ☐50 to 100US$ ☐100 to 150US$ ☐150 to 200US$ ☐200 to 250US$ ☐250 to 300US$ ☐>300US$

5.6. How far did you have to go to get your chair:

☐0 to 5km ☐5 to 10km ☐10 to 15km ☐15 to 20km ☐>20km

5.7. How many wheelchairs have you had in your life:______________________

5.8. At what age were you when you got your first chair:____________________

5.9. When did you get your current chair (age):______________________(_____)

5.10. Who paid for your chair:____

5.10.1. If cost was subsidized, how much did you pay:____________________

5.10.2. Did you borrow money to get it: ☐Yes ☐No

5.11. If you had to buy your chair, how much could you afford:

☐0US$ ☐0 to 50US$ ☐50 to 100US$ ☐100 to 150US$

☐150 to 200US$ ☐200 to 250US$ ☐250 to 300US$ ☐>300US$

5.12. Were you fitted and prescribed a chair: ☐Yes ☐No

5.12.1. If yes, by whom:____

5.13. Did you have a choice of what chair to get: ☐Yes ☐No

5.14. Did you receive training or PT with the chair: ☐Yes ☐No

5.14.1. If yes, by whom:____

5.15. Was the chair customized to fit you: ☐Yes ☐No

5.15.1. If yes, how and by whom:_______________________________________

5.16. How long did it take to get your chair: ☐0 to 1 week ☐1 week to 1 month

☐1 month to 6 months ☐6 months to 1 year ☐>1 year

5.17. Where do you get the chair repaired:

☐At manufacturer ☐At bicycle repair ☐Yourself ☐Other___________

5.18. Were you trained on how to repair the chair: ☐Yes ☐No

5.18.1. If yes, by whom:____

5.19. How good (from 1 to 10) have wheelchair services been for you:____, ☐ n/a

6 Your wheelchair

6.1. What kind of wheelchair do you primarily use:

☐4-Wheel, rear drive ☐3-Wheel, rear drive ☐Tricycle ☐Other__________

6.2. Do you have a tricycle attachment: ☐Yes ☐No ☐n/a

6.3. Do you use any other wheelchairs regularly: ☐Yes ☐No

6.3.1. If yes, explain:____

6.4. Does your frame fold: ☐Yes ☐No

6.5. What do you like about your chair, explain:_______________________________

____

6.6. What do you not like about your chair, explain:____________________________

____

6.7. Does it have a cushion: ☐Yes ☐No

6.7.1. If yes, describe cushion:____

6.8. How long do you expect the chair to last: ☐<1 year ☐1 to 5 years

☐5 to 10 years ☐10 to 15 years ☐>15 years ☐Other

6.9. How often does the chair break

☐Daily ☐Weekly ☐Monthly ☐ 6 months ☐Yearly ☐Other_______

6.10. Are there any specific parts that break easily/frequently, explain:__________

____

6.11. Does the chair roll well over the surfaces you typically have to travel:

6.11.1. On the street: ☐Yes ☐No ☐n/a

6.11.2. In your house: ☐Yes ☐No ☐n/a

6.11.3. At work: ☐Yes ☐No ☐n/a

6.11.4. Further explanation:____

6.12. Does the chair fit you and is comfortable: ☐Yes ☐No

Explain:____

6.13. How useful is the chair (rate from 1 to 10, 10 being most useful):

6.13.1. At work:_____, explain_______________________________________

6.13.2. At home:_____, explain_______________________________________

6.13.3. Traveling:_____, explain______________________________________

6.14. Do you like the looks of the chair (rate from 1 to 10, 10 liking the most):

6.14.1. Paint:_____, explain____

6.14.2. Shape:_____, explain____

6.14.3. Wheels:_____, explain____

6.15. How content are you with your chair (rate from 1 to 10, 10 being best):_____,

Explain:____

7 Wheels and tires

7.1. Rate the adequacy of the front wheels (from 1 to 10, 10 being most adequate):

7.1.1. Size:_____, explain____

7.1.2. Durability:_____, explain_____________________________________

7.1.3. Tread/traction:_____, explain__________________________________

7.2. Rate the adequacy of the rear wheels (from 1 to 10, 10 being most adequate):

7.2.1. Size:_____, explain____

7.2.2. Durability:_____, explain_____________________________________

7.2.3. Tread/traction:_____, explain__________________________________

7.2.4. Grip rail:_____, explain_______________________________________

7.3. Rate the comfort of your drive hand pedals (from 1 to 10, 10 being best):_____

Explain____, ☐n/a

8 If you don't have a wheelchair

8.1. Please explain your circumstances for not having a wheelchair:______________

____

____

9 Quality of life/well being

9.1. How is your health (rate from 1 to 10, 10 being best):_____,

Explain____

9.2. Do you feel you get enough exercise: ☐Yes ☐No

Explain____

9.3. Is your life better with your current chair than before: ☐Yes ☐No

Explain____

9.4. Are you more mobile with your new chair than your old chair: ☐Yes ☐No

Explain____

9.5. Does your new chair help you make money: ☐Yes ☐No

Explain____

9.6. Are your relationships with others better with your new chair: ☐Yes ☐No

Explain____

9.7. Are you able to participate in your community: ☐Yes ☐No

Explain____

9.8. What is your level of happiness: (rate from 1 to 10, 10 being best):_____,

Explain____

9.9. Are you stressed (rate from 1 to 10, 10 being least stressed):_____,

Explain____

9.10. Do you feel productive (rate from 1 to 10, 10 being most productive):_____,

Explain____

9.11. Rate how you feel about your job (1 to 10, 10 being best):_____, ☐n/a

Explain____

9.12. Rate your feeling of independence (1 to 10, 10 being best):_____, ☐n/a

Explain____

9.13. How far can you travel in your chair in 1 day:

☐0 to 5km ☐5 to 10km ☐10 to 15km ☐15 to 20km ☐>20km

9.14. If you are a woman, explain any gender based disability issues you have experienced or feel are important:________________________________

____

9.15. Organizations through which you meet other WC users:__________________

9.16. Any organizations you know that help WC users:_______________________

Wheelchair Factory Questions

Date of interview__________________

1) Factory info (Name, location, contact info)

2) Company info
   a) Who owns the company (Private, Govt, NGO)
   b) Do they get any assistance from anyone else
   c) If NGO, do they have a history of accountability (has it carried out a lot of projects, and is its funding public)
   d) How long has the company been in business
   e) In what area do you market/sell to
   f) Describe your customers, are they private people or organizations buying chairs for others. Do you provide payment plans
   g) Does the company produce anything else as an income gap-filler

3) Employees
   a) How many does the factory have/ how many shop workers
   b) If any, how many employees are disabled
   c) What is the level of technical skill of the employees
   d) Did they have any technical training
   e) What do they make per month
   f) Do they get a commission

4) Factory
   a) How many sq. meters is the shop and office space
   b) How many chairs are produced per month per shift
   c) How many shifts a day work

5) Equipment
   a) What are the types of equipment used

   b) How old is the equipment

   c) What kind of welding used

6) Chairs produced
   a) What kinds of chairs produced (conventional, trike, trike attachment)

   b) How many different models produced

   c) For each model, how many sold per month

   d) How many chairs sold total in life of company

   e) What is the price of the chairs

   f) Are the wheelchairs sized to the riders

   g) Do you offer a set number of sizes or do you custom make chairs

   h) Are warranties offered

7) Availability of materials
   a) Bearings
      i) What size bearings do you use for the WCs, ID and OD

      ii) Are other sizes available

   b) Tubing/Steel
      i) What sizes of tubing do you use for the WCs, ID and OD

      ii) Are there any other kinds of steel stock available, what sizes

      iii) What is the cost of mild steel

      iv) Is Chromoly available, and if so what are sizes and cost

   c) Finish
      i) Are the hand rims nickel plated

      ii) How are the frames painted

      iii) Is powder coating available (what is cost)

d) Wheels and tires
   i) Do you have 24” rims. Are they Narrow (1 3/8”) or Wide (1.75”)

   ii) What is the material and cost

   iii) Do you have 26” rims. Are they Narrow (1 3/8”) or Wide (1.75”)

   iv) What is the material and cost

   v) How much do tires and innertubes cost for each size and type of wheel

   vi) How much do spokes cost

   vii) Do the tires have solid inserts for rear wheels – cost, weight

e) Seat Fabric
   i) What kinds of fabric do you use

   ii) Is Cordura available, and if so what is the price

f) Cushion
   i) Do you make your own cushion

   ii) What is the cushion material, cost

8) Other WC orgs
   a) Can you refer us to any other wheelchair organizations with which you have been in contact/done business

9) WC riders
   a) Can you put us in touch with any WC riders

10) Any other info

Wheelchair Advocacy Groups/Organization Questions

Date of interview________________

11) Group info (Name, location, contact info)

12) Organization info
    a) What type of organization (Private, Govt, NGO)
    b) If NGO, do they have a history of accountability (has it carried out a lot of projects, and is its funding public)
    c) How long has the has the organization been around
    d) How many people are employed by the org
    e) What are the specialties of the employees

13) What is the mission statement of the organization

14) If the mission is not to directly help WC riders, what is the mission in regards to WC riders

15) What specific services towards the mission statement are provided by the organization for WC riders

16) Does the Organization focus a certain WC rider group, ie a certain disability

17) What is the geographic area served by the organization
   a) Is the org part of an international network

18) Describe how many WC riders use the org
   a) Currently
   b) Yearly
   c) During the life of the org

19) Does the org assist with purchasing wheelchairs
   a) How much of the WC cost is contributed
   b) How many WCs have been purchased
   c) What is the maximum amount that could spent on a WC
   d) How much of a choice do WC riders have in choosing a chair
   e) Where does the org buy chairs

20) Can you refer us to any other WC groups, orgs, or manufacturers
   a) Contact info

21) Can you refer us to any WC riders whom you are working with or have worked with

a) Contact info

22) Other info

Appendix B: Contact list

Wheelchair/Tricycle Advocacy Groups				
Organization Name	**Type**	**Contact Person**	**Contact Info**	**Description**
A Beacon for the Disabled (Mwangaza Kwa Wenye Ulemavu)	NGO	Ms. Paula Gremley	P.O. Box 573 Arusha, TZ, East Africa Mobile: (255) 744-305-431 email: pgremley@yahoo.com www.mwangaza.org	Focuses on people w/ disabilities in villages. Treat and educate them. Works mostly with people who have Cerebral Palsy. Brings patients from rural area to get services. Bridge gap between urban professionals and rural people. Has given out strollers in past as a mobility aid.
Comprehensive Community Based Rehabilitation in Tanzania (CCBRT) Orthopedic Workshop	NGO/ Hospital	Mr. David Charles	P.O. Box 23310 Dar es Salaam, TZ, East Africa Phone: 255-22-2601543 Fax: 255-22-2601544 Mobile: 255-741-325727 email: davidchars@yahoo.co.uk website: www.ccbrt.or.tz	Disability Hospital with full orthopedic workshop, except wheelchair fabrication. Is buying wheelchairs from Mobility Care in Arusha.
Disabled Organization for Legal Affairs	NGO	Mr. Gideon Mandesi	Kinondoni Rd, Opposite Kinondoni Muslim Secondary School, Plot 474, Block 40 P.O. Box 62963 Dar es Salaam Mobile:255-741-404240 email: gmandesi@hotmail.com	Do training courses on education, basic social services, transportaion. Use advocacy to lobby government to create more disabled services and laws.
Equal Oppertunities for All Trust Fund (EOTF)	NGO	Mr. Basil Luwemba	15 Luthuli Rd. P.O. Box 78262 Dar es Salaam, TZ, East Africa Phone: 255-22-2114512 Fax: 255-22-2114793 Mobile: 255-748-610653 email: eotf@raha.com website: www.eotf.org	Advocates for women and poverty erradication, empowerment for women, education support program for paying school fees. Gives out about 500-1000 WC Foundation chairs each year
IPP	Private Company	Ms. Joyce Luhanga	P.O. Box 4374 Dar es Salaam, TZ, East Africa Phone: 255-22-2775914 Fax: 255-22-2775916 Mobile: 255-744-775910 email: itv@ipp.co.tz, jluhanga@hotmail.com	Is a media company. Runs a free lunch for disabled people in Dar es Salaam every year. Gives out tricycles every year at lunch.

Kilimanjaro Association for Spinally Injured (KASI)	NGO	Mr. Henry Nyamubi	Moshi, TZ, East Africa Email: bernaidan@yahoo.co.uk	Mission is to affectively facilitate the rehabilitation and social integration of people with spinal chord injuries. Works a lot with people recovering at KCMC hospital. Run educational seminars. Help members purchase WCs. Councel newly injured spinal cord victims.
Monduli Handicapped Rehabilitation Center	NGO	Ms. Maghallen Shangay	P.O. Box 3044 Arusha, TZ, East Africa Phone: 027-253-8237 Fax: 027-254-8004 email: hw@habari.co.tz	Focus on physical disabilities and rehabing after surgery. Also give polio shots. Committed to giving physical and spiritual healing to handicapped persons in communities within the Roman Catholic Archidiocese of Arusha. Run village outreach programs for healthcare and education. Arrange for surgery from visiting doctors.
Muhimbili Orthopedic Institute	Gov't Hospital	Mr. Emmanuel Chitete	Muhimbili, Dar es Salaam email: emmanuelchitete@yahoo.co.uk	Orthopedic workshop based at Muhimbili National Hospital. Provides all orthopedic/prosthetic services. Will have WC workshop
Salvation Army Rehab Center	NGO/Church	Mr. Hugoline Tillya	P.O. Box 1273 Dar es Salaam, TZ	Help children with disabilities to be able to earn own income. Includes a primary school, secondary vocational school, and orthopedic workshop. Only accept kids that can go on to support themselves.
Sibusiso	NGO	Mrs. Atty Hammer-Roos	P.O. Box 14408 Arusha, TZ, East Africa Office Phone: +27-255-3320 Mobile Phone: +744-474-819 email: info@sibusiso.com	Work with children with mental disabilities. Their mission is the integration, acceptance, and education of children with mental disabilities. Much of funding from Luxury lodge on grounds. Buys all its WCs from Mobility Care, which is located on the grounds. Everyone within their network who needs a WC gets one. Will work with anyone under 18 to get a WC, and so far have been able to get funds from Liliana funds to do so every time.
Tanzania Association of the Disabled - CHAWATA	NGO	Mr. Bo Svensson	Burguruni Juu Sokoni Street P.O. Box 2361 Dar es Salaam Tel: 00255 22 2866626 Mobile: 0745-067013 email: bo.svensson@forumsyd.se	Advocates for the rights of the disabled. Mission: To change society for equality for people with disabilities. Organize people to make them independent and self-sufficient. Influence the big hospitals and government to subsidize WC prices.
Tanzania Big Game Safaris / Conservation Foundatoin Trust	NGO	Ms. Barbera Reading-Jones	P.O. Box 2458 Arusha, TZ, East Africa Phone: 255-57-250-8838 Fax: 255-57-250-8836 email: cft@tbgs.co.tz	Is a Hunting Safari Company that also runs an NGO. TZ law says hunting company has to do development and anti-poaching work. NGO gives away 1120 Wheelchair Foundation chairs every year to poor communtites in their hunting lands

Tanzania Disabled Persons Movement (TDPM)	NGO	Dr. Paul Sangija	P.O. Box 90047 Shinyanga, TZ, East Africa Phone 1: 0744 095595 Phone 2: 23 2574901 email: Tanzania_disabled@yahoo.com	Improves the livlihood of the disabled and development of people with disabilities. Develops policies which bring humanity to people with disabilities. Has also paid for 75 WCs. New project is to sensitize public and government that people with disabilities need assistance in every part of life.
Usa River Rehabilitatoin and Training Centre	NGO	Ms. Sophia Moshi	P.O. Box 47 Usa-River-Arusha Tel: 272553427/2553645 email: rehab@elct.org	Is a rehabilitation and training center. Students range from 16-30 years. Courses are offered in Carpentry and Joinery, Cloth Making, Shoe Making, Welding and Metal Fabrication, Secretarial Studies, English, Kiswahili, Religion. After their 3-year course, students are loaned equipment to start a buisness in their village. Only accept people who can go on to help themselves. 63 students total
UWZ (Zanzibar Association of the Disabled)	NGO	Mr. Khalfan H. Khalfan	P.O. Box 2043 Zanzibar, TZ, East Africa Phone: 255-24-2232533 Fax: 255-24-2231730 email: uwz@zanzinet.com	Creates awareness and advocates for equal rights and the dignity of persons with disabilities through emopowering people to contribute their experience, tallencts and capabilites to national and international development. Does community based rehab for children. Runs a wheelchair workshop.
Wonder Welders	NGO	Elly ???	P.O. Box 70045 Dar es Salaam, TZ, East Africa Phone: 255-744-051417 email: info@wonderwelders.org website: www.wonderwelders.org	A group of polio surviors who make art out of scrap metal. Organization is completely self-sustained.
Yombo Vocational Rehabilitation Center	NGO	Mr. Nso Mkunda	P.O. Box 40302 Dar es Salaam, TZ, East Africa Tel: 022-2863943 mobile: 0744-496526 website: www.furuboda.se/yombo	Teaches disabled people trade skills. Skills include: tayloring, shoe making, clerical duties, carpentry, computer skills, and fabric dying.
Youth Disabilites Development Forum (YDDF)	NGO	Mr. Joseph Alili	P.O. Box 837 Dar es Salaam, TZ, East Africa Phone: 255-741-307082 Phone: 255-744-307082 email: yddf@yahoo.com	Giving youth with disability the skills to build their capacity as effective leaders of developemnt and able to adjust to society. Promote recognition of needs of disabled for education, health, politics, economics, and activities.
Wheelchair/Tricycle Manufacturers				
Organization Name	**Type**	**Contact Person**	**Contact Info**	**Description**

Jaffery Industries, Saini Limited	Private company	Vishal Saini	60 Chang'ombe Rd. P.O. Box 5416 Dar es Salaam, TZ, East Africa Phone: 255-744-609999 Fax: 255-22-2862877 email: vishals111@hotmail.com	Manufacturer of tricycles and wheelchairs. Also produces hospital equipment, school uniforms, and office furnature.
Usa River Rehabilitatoin and Training Centre, Welding and Fabricatoin Workshop	NGO	Mr. Mrema	P.O. Box 47 Usa-River, Arusha, East Africa Tel: 272553427/2553645 email: rehab@elct.org	Makes tricycles and has made one wheelchair. Also does other custom metal work. Teaches students at Usa River about metal work and fabricatoin.
Mobility Care Wheelchairs	Non-profit Business	Mr. Daniel Namkessa	P.O. Box 14408 Arusha, TZ, East Africa Phone: 255-748-203133 Mobile: 255-744-855713 email: mobilitycare@wheelchairs.co.tz website: www.wheelchairs.co.tz	Wheelchair workshop run by two TATCOT WTTC graduates. They make 2 styles of wheelchairs and one child's wheelchair.
Kilimanjaro Christain Medical Center (KCMC) Wheelchair Workshop	Non-profit Business	Mr. Abdullah Munish	P. O. Box 8690 Moshi, TZ, East Africa email: abdumasus@yahoo.com	Wheelchair workshop run by TATCOT WTTC graduate. They make 2 styles of wheelchairs and one child's wheelchair
Disabled Aids and General Engineering (DAGE), part of SIDO	Private company	Mr. Henry Chacha	Nyerere Rd. Plot No. 24/27, Block 13 (G) P.O. Box 40584 Dar es Salaam, TZ, East Africa email: (Henry can be contacted through his friend Erasto at) erastoelias@hotmail.com	Produces tricycles and does custom metal fabrication. Six disabled employees. Henry has attended wheelchair congress in the past, and attempted to make Whirlwind chair. Would like very much to start a wheelchair workshop at DAGE.
UWZ (Zanzibar Association of the Disabled) Wheelchair Workshop	part of UWZ NGO	Ms. Salma H. Saadat	P.O. Box 2043 Zanzibar, TZ, East Africa Phone: 255-24-2233719 Fax: 255-24-2231730 email: uwz@zanzinet.com	Workshop that produces wheelchairs and tricycles. Tricycle produced is a Whirlwind model. All the workers are disabled. The shop is funded by UWZ. UWZ no longer has manpower to manage shop, so trying to make the shop independent, give to the technitions, or sell to another company.
Palray Limited	Private company	Mr. Thomas Watson, sales manager	P.O. Box 1916 Dar es Salaam, TZ, East Africa Phone: 255-22-2861920 Fax: 255-22-2861920 email: mpalray@hotmail.com	Manufactures tricycles, hospital wheelchairs. Also makes hospital and office furnature.
Muhimbili Wheelchair Workshop	Part of government hospital	Mr. Emmanuel Chitete	Muhimbili, Dar es Salaam email: emmanuelchitete@yahoo.co.uk	Workshop has yet to start producing wheelchairs. Is still in the process of procuring materials, setting up equipment, etc. Mr. Chitete is a graduate of the TATCOT WTTC and is currently working in Muhimbili's orthopedic workshop.
Parts/material suppliers				

Organization Name	Type	Contact Person	Contact Info	Description
Doshi Hardware	Private company	Mr. Milaro, Director	P.O. Box 438 Dar es Salaam, TZ, East Africa Phone: 255-22-2866215 Mobile: 255-748-780940 email: doshitz@africaonline.co.tz	Supplier of steel of all sizes. Can ship anywhere in TZ. People from all over TZ use Doshi. There is no minumum size per order.
Burhani Cycle Mart	Private Company	Mr. Mustafa	Kariakoo Dar es Salaam, TZ, East Africa Phone: 255-22-2182281	Sells bicycle components of all sizes. Largest bicycle part supplier found in TZ. Also carries frame components, like bottom braket and head tube flanges. Can order anything, and can offer prices for parts bought in bulk.

Appendix C: Wheelchair rider interview results

Category							
	#						
Total # people interviewed	71						
	Male	Female					N/A
Sex	53	18					
	0-9	10-19	20-29	30-39	40-49	50+	N/A
Age		10	13	21	12	2	12
	Rural	Urban					N/A
Resides now	16	41					14
	0-4km	5-9km	10-14km	15-19km	20+km		N/A
Distance of home to nearest city	33	3	3	3	12		17
	Bus	Taxi	WC	Trike	Friend	Crawl	N/A
Primary means of transport	13	6	28	30		4	5
	Paved	Dirt rd/bumpy	Mountains	Coast/sand/wet	Hot/Sand/rock	Other	N/A
Surfaces of travel	35	28	5	4	35	1	15
	Yes	No					N/A
Attended School	60	3					8
	Yes	No					N/A
Disability prevent schooling	14	38					19
	Primary	Secondary	College	University	Post-Graduate		N/A
Highest schooling attained	42	4	12				13
	Own	Rent	Free in another's	Shelter	On street	other	N/A
Housing	19	17	8	5	4	2	16
	Alone	w/ Family	w/ Friends	Other			N/A
Live with	13	44					13
	Spouse	Children	Parents	Other relatives			N/A
What family members do you have	20	28	24	7			12
	Yes	No	Student				N/A
Have a job currently	24	18	24				5

	$0US	$0 to 29US	$30 to 59US	$60 to 89US	$90 to 119US	$120 to 149US	≥150US	Student	N/A
Monthly income	4	9	8	11	3	1		25	10

	Yes	No					N/A
Gov't help w/ income	15	50					8

	Yes	No	Student				N/A
enough money to support self	5	35	20				12

	0 to 4km	5 to 9km	10 to 14km	15 to 19km	≥20km	N/A
How far travel to work/school	30	9	5	1	2	24

	Bus	Taxi	WC	Trike	Friend	Crawl	Other	N/A
How do travel to work/school	10		21	29		1	2	13

	Birth Defect	Polio	Spinal Injury	Cerebral Palsy	Other		N/A
What caused disability	12	27	14		10		9

	Crawling	Cane	Crutches	Push Cart	Other	N/A
Before current WC/Trike, how move	35	5	9		5	17

	Yes	No					N/A
Is anyone else in family disabled	8	46					17

	Yes	No					N/A
Continue medical treatment for disability	25	33					13

	Yes	No					N/A
Do you have a WC/Trike	63	7					

	Yes	No					N/A
Was your chair/trike made in TZ	31	32					9

	KCMC	Mobility Care	TATCOT Grad	WC Foundation	Imported	Other TZ		N/A
If have WC, who made	2			7	20			8

	Palray (trike)	SIDO (trike)	Jaffery (trike)	Usa River	Canada	Imported	Other TZ	N/A
If have trike, who made	16	9			3	3	2	13

	$0US	$0 to 49US	$50 to 99US	$100 to 149US	$150 to 199US	$200 to 249US	$250 to 299US	≥$300US	N/A
How much did WC/trike cost		1	2	11	11	1	1	6	39

	0 to 4km	5 to 9km	10 to 14km	15 to 19km	≥20km		N/A
How far have to go to get WC/trike	38	8	2		7		15

	0	1	2	3	4	≥5	N/A
How many WC/trike had during life		18	24	6	1	2	20

	0-9	10-19	20-29	30-39	40-49	50+	N/A
At what age get first chair	5	18	16	10	1		21

	0-9	10-19	20-29	30-39	40-49	50+	N/A
At what age get current chair	1	12	15	14	7		24

	Yourself /family	Gov't	NGO/Church/Mosque	Hospital	Business/ donation	Chair manufac.	Other	N/A
Who paid for majority of your WC/trike	9	3	37	1	2		13	8

	$0US	$0 to 49US	$50 to 99US	$100 to 149US	$150 to 199US	$200 to 249US	$250 to 299US	≥$300US	N/A
How much did you contribute for your WC/trike	39	2	1	3	3		1	1	22

	$0US	$0 to 49US	$50 to 99US	$100 to 149US	$150 to 199US	$200 to 249US	$250 to 299US	≥$300US	N/A
If bought chair now, how much you afford	18	19	2	2					20

	Yes	No					N/A
Were you fitted/prescribed your WC/trike	5	39					25

	Yes	No					N/A
Choice of what WC/trike to get	8	37					24

	Yes	No					N/A
Get training or PT with WC/trike	13	40					21

	Yes	No					N/A
Was WC/trike customized to fit you	10	33					26

	0 to 1 week	>1week, <1month	>1month,<6 months	>6months,<1year	>1year		N/A
How long did it take to get your WC/trike	21	9	12	2	4		23

	At manufact.	Bicycle shop	Yourself	Other			N/A
Where do you get WC/trike repaired	1	33	9	17			21

	Yes	No					N/A
Were you trained to repair yourself	4	43					22

	1	2	3	4	5	6	7	8	9	10	N/A
How have WC/trike services been (rank)	3	1			7		1		1	16	37

	4-Wheeler	3-Wheeler	Tricycle	Other			N/A
Kind of WC/trike primarily use	24	5	34				11

	Yes	No					N/A
Have a tricycle attachment	4	32					35

Impromptu added question	WC	Tricycle					N/A
*If had to choose b/w WC or Trike, what choose	7	13					

Impromptu added question	Yes	No					N/A
*Think WC with trike attachment is best solution	19						1

	Yes	No					N/A
Use other WC/Trike regularly (beyond primary)	8	37					26

	Yes	No					N/A
Does your frame fold	22	36					14

	Yes	No					N/A
Does your WC/Trike have a cushion	42	16					14

	<1yr	1, <5yrs	5, <10yrs	10, <15yrs	>15yrs		N/A
How long do you expect your WC/trike to last	11	22	6	5	4		25

	Never has	Daily	Weekly	Monthly	Every 6 months	Yearly	Other	N/A
How often does your WC/trike break	12	6	14	8	3		1	26

	Yes	No					N/A
Does the chair fit and is comfortable	36	19					25

	1	2	3	4	5	6	7	8	9	10	N/A
How useful is WC/Trike at work (rate 1-10)	3	1	1		2			2	5	23	34

	1	2	3	4	5	6	7	8	9	10	N/A
How useful is WC/Trike at home (rate 1-10)	16	2	1		6			1	1	9	35

	1	2	3	4	5	6	7	8	9	10	N/A
How useful is WC/Trike traveling (rate 1-10)	15	3	1		5		1		2	9	35

	Yes	No					N/A
Do you like the looks of the chair	32	17					23

	1	2	3	4	5	6	7	8	9	10	N/A
How content with chair are you (rate 1-10)	2		1		8	1	1	3	4	19	26

	1	2	3	4	5	6	7	8	9	10	N/A
Adequacy of the front wheels (rate 1-10)		1	2	3	2	1	6	6		7	35

	1	2	3	4	5	6	7	8	9	10	N/A
Adequacy of the rear wheels (rate 1-10)		2	1	5		1	6	4	1	8	35

	1	2	3	4	5	6	7	8	9	10	N/A
If use trike, comfort of hand pedals (rate 1-10)	2				4		1	1	1	12	50

	No money	WC/trike is broken	Other				N/A
If don't have WC/Trike, what is reason	6		1				64

	1	2	3	4	5	6	7	8	9	10	N/A
How is your health (rate 1-10)	2	1		1	12	1	4	3	4	24	19

	Yes	No					N/A
Do you get enough exercise	38	15					18

	Yes	No					N/A
Is life better than before your current WC/trike	41	5					24

	Yes	No					N/A
More mobile with current WC/trike than before	44	2					25

	Yes	No	Student				N/A
Does your WC/trike help you make money	29	5	13				24

	Yes	No					N/A
Better relationships w/ others with WC/trike	45	2					24

	Yes	No					N/A
Able to participate in your community	41	12					28

	1	2	3	4	5	6	7	8	9	10	N/A
How happy are you (rate 1-10)	4				5	1	2		3	32	23

	1	2	3	4	5	6	7	8	9	10	N/A
How stressed are you (rate 1-10, 1 most stressed)	16	2	4		6	1	2	1	1	13	24

	1	2	3	4	5	6	7	8	9	10	N/A
How productive are you (rate 1-10)	9	1	1		7	2	1	4	5	10	24

	1	2	3	4	5	6	7	8	9	10	N/A
How much you like job/school (rate 1-10)	2				1			2	3	23	24

	1	2	3	4	5	6	7	8	9	10	N/A
How independent do you feel (rate 1-10)	7	2			10		3	1	3	21	24

	0-4km	5-9km	10-14km	15-19km	20+km		N/A
How far can you travel in one day (for WC user)	16		2		1		10

	0-4km	5-9km	10-14km	15-19km	20+km		N/A
How far can you travel in one day (for Trike user)	11	10	3		7		5

Appendix D: Doshi steel prices

These sheets are the inventory catalog of steel sizes for Doshi Hardware, as of July 2005.

DOSHI
GROUP OF COMPANIES

Doshi Hardware (T) Ltd.,

REF. NO. 2005/05/12

Tel.2866215/17.

e-mail:doshitz@africaonline.co.tz

pieces per ton — govt tax — total price

PRICE LIST W.E.F. MAY. 12, 2005.

BLACK PIPE CLASS - A X 6MTRS.					GALAVANISED PIPE CLASS - A X 6MTRS.				
SIZE	PC/TON	BASIC	VAT	WITH VAT	SIZE	PC/TON	BASIC	VAT	WITH VAT
½"	175	7,730	1,546	9,276	½"	160	10,160	2,032	12,192
¾"	117	11.460	2.292	13.752	¾"	109	15.050	3.010	18.060
1"	82	16.490	3.298	19.788	1"	76	21.385	4.277	25.662
1¼	64	21,130	4,226	25,356	1¼	59	27,550	5,510	33,060
1½"	51	26.510	5.302	31.812	1½"	47	35.330	7.066	42.396
2"	40	33,810	6,762	40,572	2"	37	45,150	9,030	54,180
2½"	28	48,290	9,658	57,948	2½"	26	62,510	12,502	75,012
3"	24	56,340	11,268	67,608	3"	22	73,875	14,775	88,650
4"	16	110,040	22,008	132,048	4"	15	137,300	27,460	164,760

BLACK PIPE CLASS - B X 6MTRS.					GALAVANISED PIPE CLASS - B X 6MTRS.				
SIZE	PC/TON	BASIC	VAT	WITH VAT	SIZE	PC/TON	BASIC	VAT	WITH VAT
½"	136	10.060	2.012	12.072	½"	125	13.330	2,666	15.996
¾"	105	13,030	2,606	15,636	¾"	97	17,350	3,470	20,820
1"	68	20,120	4,024	24,144	1"	63	26,880	5,376	32,256
1¼	53	25.820	5.164	30.984	1¼	49	34.720	6.944	41.664
1½"	46	29,750	5,950	35,700	1½"	42	39,680	7,936	47,616
2"	32	42,760	8,552	51,312	2"	30	57,470	11,494	68,964
2½"	25	54,740	10,948	65,688	2½"	23	72,460	14,492	86,952
3"	19	72,020	14,404	86,424	3"	16	98,030	19,606	117,636
4"	13	140,700	28,140	168,840	4"	13	172,150	34,430	206,580
5"	10	176,600	35,320	211,920	5"	10	205,000	41,000	246,000
6"	8	209,000	41.800	250,800	6"	8	270.650	54,130	324.780
8"	6	276,000	55,200	331,200	8"	6	382,300	76,460	458,760

BLACK PIPE CLASS - C X 6MTRS.					GALAVANISED PIPE CLASS - C X 6MTRS.				
SIZE	PC/TON	BASIC	VAT	WITH VAT	SIZE	PC/TON	BASIC	VAT	WITH VAT
½"	114	12,200	2,440	14,640	½"	110	20,100	4,020	24,120
¾"	87	16,000	3,200	19,200	¾"	85	25,600	5,120	30,720
1"	57	25.000	5.000	30.000	1"	54	41.700	8.340	50.040
1¼	43	32,300	6,460	38,760	1¼	42	51,200	10,240	61,440
1½"	37	37,400	7,480	44,880	1½"	36	58,800	11,760	70,560
2"	27	52,000	10,400	62,400	2"	26	77,800	15,560	93,360
2½"	21	92,340	18,468	110.808	2½"	20	103.525	20,705	124.230
3"	16	119,350	23,870	143,220	3"	16	129,360	25,872	155,232
4"	11	163,400	32,680	196.080	4"	11	189,210	37.842	227,052
5"	9	213,300	42,660	255,960	5"	9	228,900	45,780	274,680
6"	8	247,645	49,529	297,174	6"	7	298,725	59,745	358,470
8"	5	382,300	76,460	458,760	8"	5	458,000	91,600	549,600

THE ABOVE PRICES ARE SUBJECT TO CHANGE WITHOUT PRIOR NOTICE.

MR MILAN - DOSHI - Director
0748-780940
Box 438
DSM

Page # 1 of 5

- people from all over country use Doshi

Tel.2866215/17.
e-mail:doshitz@africaonline.co.tz

PRICE LIST W.E.F. MAY. 12, 2005.

SQUARE HOLLOW SECTION X 6MTRS.

SIZE	PC/TON	BASIC	VAT	WITH VAT
20X20X1.0	270	4,850	970	5,820
20X20X1.2	235	6,530	1,306	7,836
20X20X1.6	191	7,700	1,540	9,240
25X25X1	220	6,100	1,220	7,320
25X25X1.2	186	8,260	1,652	9,912
25X25X1.6	147	9,810	1,962	11,772
25X25X2.0	116	16,640	3,328	19,968
30X30X1.2m	154	9,925	1,985	11,910
30X30X1.6m	124	11,865	2,373	14,238
30X30X2.0m	95	18,390	3,678	22,068
40X40X1.2	114	13,410	2,682	16,092
40x40x1.6	92	15,990	3,198	19,188
40X40X2.0	70	23,370	4,674	28,044
40X40X3.0	48	32,910	6,582	39,492
40X40X4.0	36	42,770	8,554	51,324
50X50X1.2	89	17,010	3,402	20,412
50X50X1.5	78	20,108	4,022	24,130
50X50X2.0	58	27,900	5,580	33,480
50X50X3.0	35	41,970	8,394	50,364
50X50X4.0	28	54,610	10,922	65,532
60x60x1.5	60	25,990	5,198	31,188
60X60X2.0	45	31,170	6,234	37,404
60x60x3.0	35	44,570	8,914	53,484
75X75X3.0	25	73,184	14,637	87,821
75X75X4.0	19	96,340	19,268	115,608
100X100X3	18	99,530	19,906	119,436
100X100X4	14	130,690	26,138	156,828
100X100X6	9	192,710	38,542	231,252
150X150X3	11	151,000	30,200	181,200
150X150X4	6	199,250	39,850	239,100
150X150X6	6	299,250	59,850	359,100

Z-PURLINS X 6MTRS.

SIZE	PC/TON	BASIC	VAT	WITH VAT
4'X2'X2mm	44	33,000	6,600	39,600
5'X2'X2mm	40	36,917	7,383	44,300
6"X2"X2"	38	40,000	8,000	48,000

HOLLOW SECTION (RECTANGULAR) X 6MTRS

SIZE	PC/TON	BASIC	VAT	WITH VAT
40X25X1.2	141	10,840	2,168	13,008
40X25X1.6	114	12,910	2,582	15,492
40X25X2.0	87	19,980	3,996	23,976
50X25X1.2	122	12,630	2,526	15,156
50X25X1.6	98	15,450	3,090	18,540
50X25X2.0	74	24,110	4,822	28,932
50X25X3.0	51	31,060	6,212	37,272
60X40X1.2	91	17,010	3,402	20,412
60X40X1.5	73	21,790	4,358	26,148
60X40X2.0	55	26,920	5,384	32,304
60X40X3.0	33	41,970	8,394	50,364
60X40X4.0	25	54,610	10,922	65,532
75X50X2.0	44	32,400	6,480	38,880
75X50X3.0	35	44,900	8,980	53,880
75X50X4.0	18	59,800	11,960	71,760
100X50X2	37	39,650	7,930	47,580
100X50X3	25	69,333	13,867	83,200
100X50X4	19	92,400	18,480	110,880
125X75X2		72,775	14,555	87,330
125X75X3	18	94,350	18,870	113,220
150X50X3	18	86,850	17,370	104,220
150X50X4	14	113,275	22,655	135,930
150X100X4	11	141,550	28,310	169,860
200X100X4	9	171,750	34,350	206,100
200X100X6	6	255,900	51,180	307,080

HOLLOW SECTION (CIRCULAR) X 6MTRS.

SIZE	PC/TON	BASIC	VAT	WITH VAT
16X1.5mm		5,985	1,197	7,182
20X1.2mm	300	5,260	1,052	6,312
20X1.6mm	225	6,440	1,288	7,728
25x1.2mm	222	6,720	1,344	8,064
25x1.6mm	165	8,450	1,690	10,140
32X1.2 mm	183	8,200	1,640	9,840
32x1.5 mm	150	10,920	2,184	13,104
38x1.2 mm	150	10,650	2,130	12,780
38x1.5mm	137	13,440	2,688	16,128
42x1.2mm	136	12,230	2,446	14,676
42x1.5mm	120	14,650	2,930	17,580
48x1.2mm	120	13,800	2,760	16,560
48x1.5mm	97	16,175	3,235	19,410
62x1.5mm	77	20,425	4,085	24,510

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.S. PLATE 2.4X1.2 MTRS

SIZE	PC/TON	BASIC	VAT	WITH VAT
8'X4'X0.8m	53	19,925	3,985	23,910
8'X4'X1.0m	43	24,560	4,912	29,472
8'X4'X1.2m	35	31,060	6,212	37,272
8'X4'XX1.5n	27	39,570	7,914	47,484
8'X4'X2.0m	21	46,530	9,306	55,836
8'X4'X2.5m	17	57,470	11,494	68,964
8'X4'X3.0m	14	69,790	13,958	83,748
8'x4'x4.0 mr	11	97,710	19,542	117,252
8'x4'x4.5 mr	9	108,560	21,712	130,272
8'x4'x6.0 mr	7	141,430	28,286	169,716
8'x4'x8.0 mr	5	198,000	39,600	237,600
8'x4'x10 mm	4	303,300	60,660	363,960
8'x4'x12 mm	4	370,600	74,120	444,720
8'x4'x15 mm	3	461,900	92,380	554 280
8'x4'x20 mm	2	559,600	111,920	671,520
8'x4'x25 mm	2	701,200	140,240	841,440

PASPEX SHEETS

SIZE	PC/TON	BASIC	VAT	WITH VAT
6'X4'X2mm		43,000	8,600	51,600

CHEQUERED PLATE

SIZE	PC/TON	BASIC	VAT	WITH VAT
8'X4'X3.0 m	14	71,180	14,236	85,416
8'X4'X4.5 m	9	110,720	22,144	132,864
8'X4'X6.0 m	7	145,850	29,170	175,020

CHAINLINK FENCING

SIZE	PC/TON	BASIC	VAT	WITH VAT
15mX6'X2.5mm		49,000	9,800	58,800
15mX6'X2.0mm		40,000	8,000	48,000

BRC

SIZE	PC/TON	BASIC	VAT	WITH VAT
150'X5'		145,833	29,167	175,000

WELD MESH

SIZE	PC/TON	BASIC	VAT	WITH VAT
8'X4'		7,083	1,417	8,500

BINDING WIRE

SIZE	PC/TON	BASIC	VAT	WITH VAT
BW	25 KG	23,750	4,750	28,500
BW	50 KGS	47,083	9,417	56,500

Z-SECTION

SIZE	PC/TON	BASIC	VAT	WITH VAT
20X20X6mm		4,750	950	5,700
25X25X6mm		8,166	1,633	9,799

CHANNELS X 6MTRS

SIZE	PC/TON	BASIC	VAT	WITH VAT
75X40X6m	19	62,975	12,595	75,570
100X50X6n	15	67,925	13,585	81,510
125X65X6n	12	99,550	19,910	119,460
150X75X6n	9	121,275	24,255	145,530
H/R 200X75mm		204,600	40,920	245,520

STRAINING WIRE GALV.

SIZE & LENGTH	BASIC	VAT	WITH VAT
2.5mmX 50kg	54,166	10,833	64,999

REINFORCING BARS PRICE PER TON

SIZE	PC/TON	BASIC	VAT	WITH VAT
ROUND 8.0 mm		833,333	166,667	1,000,000
ROUND10mm		741,666	148,333	889,999
ROUND 12-25mm		725,000	145,000	870,000
H.T.D. 8.0mm		833,333	166,667	1,000,000
H.T.D. 10.0mm		791,666	158,333	949,999
H.T.D.12.0-25.0mm		766,666	153,333	919,999

SQUARE BARS

SIZE	PC/TON	BASIC	VAT	WITH VAT
SQB10 mm 213 Pcs		4,500	900	5,400
SQB12 mm 149 Pcs		5,200	1,040	6,240
SQB16 mm105 Pcs		9,000	1,800	10,800

GALV. PLAIN SHEETS

SIZE	PC/TON	BASIC	VAT	WITH VAT
26G.GI 0.4		17,416	3,483	20,899
24G.GI 0.6	71	22,000	4,400	26,400
22G.GI.0.8	53	32,000	6,400	38,400
20G.GI1.0 r	43	36,200	7,240	43,440
18G.GI.1.2	35	42,200	8,440	50,640
16G.GI.1.5	28	50,875	10,175	61,050

STAINLESS STEEL SHEETS

SIZE	BASIC	VAT	WITH VAT
8'X4'X0.5 mm		-	-
8'X4'X1.0 mm	165,400	33,080	198,480
8'X4'X1.2 mm	192,900	38,580	231,480
8'X4'X1.5 mm	220,500	44,100	264,600
8'X4'X2.0 mm	276,700	55,340	332,040
8'X4'X3.0 mm	393,200	78,640	471,840
8'X4'X4.0 mm	589,900	117,980	707,880
	785,900	157,180	943,080

GABION BOXES

SIZE	PC/TON	BASIC	VAT	WITH VAT
2X1X1'		40,000	8,000	48,000

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M.S. ANGLES X 6MTRS.					M.S. FLAT BARS X 6MTRS.				
SIZE	WGT/PE IN KG	BASIC	VAT	WITH VAT	SIZE	WGT/PE IN KG	BASIC	VAT	WITH VAT
20X20X3m	5.36	4.583	917	5,500	20X3mm	2.9	2.875	575	3.450
20X20X4m	7.0	6.166	1.233	7.399	20X4mm	3.8	3.833	767	4.600
25X25X3m	6.70	6.375	1.275	7.650	20X6mm	5.7	5,292	1.058	6.350
25X25X4m	8.8	8.000	1.600	9,600					
25X25X6m	12.5	11,250	2,250	13,500	25X3mm	3.6	3,542	708	4,250
					25X4mm	4.8	4,375	875	5,250
30X30X3m	8.2	7,625	1,525	9,150	25X6mm	7.1	6,583	1,317	7,900
30X30X4m	10.7	9,542	1,908	11,450					
30X30X6m	15.3	13,833	2.767	16,600	30X3mm	4.3	4,042	808	4 850
					30X4mm	5.7	5,000	1,000	6,000
40X40X3m	11.1	9,750	1,950	11,700	30X6mm	8.5	7,583	1,517	9.100
40X40X4m	14.6	13,125	2,625	15,750					
40X40X6m	21.2	18,417	3,683	22,100	40X3mm	5.7	5,000	1,000	6,000
					40X4mm	7.4	6,750	1,350	8,100
50X50X3m	14	12,417	2,483	14,900	40X6mm	11.3	9,958	1,992	11,950
50X50X4m	18.4	16,375	3,275	19,650	50X2mm			-	-
50X50X6m	26.9	23,583	4,717	28,300	50X3mm	7.1	6,375	1,275	7,650
					50X4mm	9.3	8,417	1.683	10,100
65X65X6m	34.8	33,750	6,750	40,500	50X6mm	14.2	12,500	2,500	15,000
					50X10mm		20,833	4,167	25,000
75X75X6m	40.80	38,000	7,600	45,600	60X9mm			-	-
100X100X9mm		95,850	19,170	115,020	75X6mm	21.2	19,167	3,833	23,000
120X120X8mm			-	-	100x6mm		29,500	5,900	35,400
150X150X10mm		115,000	23,000	138,000	100X8mm	39.0	39,333	7,867	47,200
					100X12mm		50,000	10,000	60,000
UNIVERSAL BEAMS (12m)					I- BEAMS X 6MTRS.				
SIZE	WGT/MT IN KG	BASIC	VAT	WITH VAT	SIZE	WGT/PE IN KG	BASIC	VAT	WITH VAT
203X133X25kg		414,000	82,800	496,800	100X50mm	49	55,800	11,160	66,960
254X146X31kg		513,500	102,700	616,200	120X64mm	62	71,750	14,350	86,100
305X165X40kg		662,500	132,500	795,000	160X82mm	95	109,000	21,800	130,800
356X171X45kg		678,500	135,700	814,200	180X91mm	113	129,750	25,950	155,700
					200X100m	134	154,500	30,900	185,400
U- COLUMNS (12 mtrs)					EXPANDED METAL				
SIZE	WGT/MT	BASIC	VAT	WITH VAT	SIZE	PACK	BASIC	VAT	WITH VAT
152X152X23kg		381,000	76,200	457,200	8'X4'X1mm	5 PCS	28,333	5,667	34,000
203X203X46kg		762,000	152,400	914,400					
254X254X73kg		1,208,000	241,600	1,449,600					
305X305X97kg		1,590,000	318,000	1,908,000					

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R.I. BARS PRICE PER PIECE

SIZE	PC/TON	BASIC	VAT	WITH VAT
6.0 mmx50kg/264mtrs		65.000	13,000	78.000
8.0 mm	210	3.917	783	4.700
10.0 mm	135	5.617	1,123	6,740
12.0 mm	94	7,890	1,578	9,468
16.0 mm	53	13,993	2,799	16,792
20.0 mm	34	21,813	4,363	26,176
25.0 mm	22	33,712	6,742	40,454

PHILIPS F.T.L. & BULB PRICE PER PIECE

SIZE	PC/BOX	BASIC	VAT	WITH VAT
4 FT.	25	940	188	1,128
222 FT.	25	850	170	1.020
40W-100W	120	275	55	330

POLY TANK

SIZE	PC/TON	BASIC	VAT	WITH VAT
500 LTR.			-	-
1000 LTR.			-	-
2000 LTR.			-	-
3000 LTR.			-	-
5000 LTR.			-	-

NAILS

SIZE	PACK	BASIC	VAT	WITH VAT
1" -1½"	50 KGS	52,500	10,500	63,000
2",2½",3"	50 KGS	47.500	9.500	57.000
			-	-

CUTTING DISC / GRINDING DISC

SIZE		BASIC	VAT	WITH VAT
Dronco C 4"		1.500	300	1.800
Dronco C 5"		1.650	330	1.980
Dronco G 4"		2.000	400	2.400
Dronco G 5"		2,200	440	2,640

M.S. SHAFTING X 6MTRS.

SIZE	WGT/PE	BASIC	VAT	WITH VAT
½"	5.94		-	-
¾	13.44		-	-
1"	23.88		-	-
1¼"	37.26	55,000	11,000	66,000
1½"	53.70	80,000	16,000	96,000
1¾"	73.08		-	-
2"	95.40	137,000	27,400	164 400
2¼"	120.78		-	-
2½"	180.42	230,000	46,000	276,000
3"	214.66	350,000	70,000	420,000
4"	381.66	675,000	135,000	810 000

HTD BARS PRICE PER PIECE

SIZE	PC/TON	BASIC	VAT	WITH VAT
8mm	210	3,917	783	4 700
10mm	135	5,987	1,197	7,184
12mm	94	8.333	1.667	10.000
16mm	53	14.779	2.956	17.735
20mm	34	23,039	4,608	27,647
25mm	22	35,606	7,121	42,727

CUTTING/GRINDING/ STONE C. DISCS

SIZE	PC/PCK	BASIC	VAT	WITH VAT
Pferd C 7"	25	2,000	400	2,400
Pferd C 9"	25	2,400	480	2,880
Pferd G 7"	10	3,625	725	4 350
Dronco G 7	10	3.700	740	4.440
Dronco G 9	10	4,675	935	5,610
DroncoSC 9	10	3,300	660	3,960
Dronco C14	10	8,500	1.700	10.200
Dronco C 7"	25	2.125	425	2.550
Dronco C 9"	25	2.600	520	3.120
Pfred C 14"	10	8,304	1,661	9,965

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Appendix E: Bicycle components

Components and prices in this section are from Burhani Cycle Mart.

Item description	Available sizes	Price
Stem cupset with loose bearings		$1.00US
Stem cupset with caged bearings		$2.50US
Bottom bracket shell		$2.00US
Bottom bracket shell with bearings		$4.00US
Stem and tube frame brackets		$1.50US each
Fork		$3.50US
Crank	28, 32, 36, 44, 48, 52 tooth	$3.50US
Front hub		$0.20 to $1.00US
Rear hub		$1.50US
Sprockets	16, 18, 20 tooth	
Rims	28 X 1.5, 36 holes	

Appendix F: Comments on WTTC manuals

This section is divided up by manual. Each comment corresponds to the content in the manual on the reported page. Only the manuals that are related to engineering were evaluated.

Wheelchair Design

p. 19 – There is no analysis presented, no identification of design constraints, and no breaking down the design “problem” into functional requirements – e.g. sometimes the design brief will include multiple requirements the design has to fulfill.

p. 25 – No strategy in the design – there needs to be a general strategy of how to solve the problem before concepts are generated. Making concepts too early can quickly limit design flexibility.

p. 46 – How are the necessary tolerances determined?

p. 51 – The hub design is over constrained, just like the caster barrel.

p. 55 – The axle is very complicated to make, and has to be made on a lathe.

p. 57 – The hub spacer does NOT spread load over 2 bearings, their position (dictated by the hub shoulders) does. The hub spacer may not prevent bearing damage at all, and may actually cause more damage (see Figure 2.22 of this document).

p. 61 – Are solid inner tubes made? Could they be made in Tanzania using the same process as the Zimbabwe wheel? Tire blowout is a very common problem.

p. 68 – Why can't the whole caster wheel be cast onto a bicycle hub using on one density of rubber? Some tests need to be performed to determine the feasibility of this idea. If shock absorption desired, some compliance could be designed into the wheelchair frame.

p. 69 – The locknut has a nylon insert. How available are these in remote villages?

p. 73 – For the brakes, could the overlock rod be bent to include a feature for a stop? If so, the stop rod would not be necessary. Could the brake be made out of one bent piece?

p. 87 – So many different pieces in 3-wheeler frame!!! Why so complex?

p. 110 – What pressure on the skin will cause a pressure sore? Is it a function of blood pressure?

p. 118 – Is there any mechanical data available on foam?

p. 126 – "The main drawback of a tricycle attachement is its cost, which can be almost as much as the wheelchair itself. The complexity of the design can also be a stumbling block for local workshops."
Neither of these statements are substantiated or true. If they were, why can tricycles be made for $100US less than wheelchairs?

p. 131-142 – Wheelchair strength testing: kilogram is a unit of mass, not force. That should be made clear. Why are different weights used for different tests? If the weight is supposed to simulate a rider, shouldn't it be the same for all tests?

p. 141 – Test 14: The bending stress in the axle should be calculated for this test to see if it exceeds the yield stress.

Good Wheelchairs

p. 10 – Why are there no designs for a 3-wheeled folding wheelchair? A 3-wheeled design is stable because it is kinematically constrained with the ground (called the milking stool principle in the manual). This is not necessarily true – a 3-wheeler might be easier to tip in many cases, but less likely to rock back and forth over rough ground.

p. 12 – "Anything that weights less than 14kg may not be strong enough." This statement is not true. Look at steel bicycle frames as a counterexample. Steel bicycle frames are only marginally heavier than ones made of aluminum or carbon fiber frames.

p. 12 – on what basis is 22mm diameter tubing the best size for frames? Larger diameter tubing has a larger second moment of area, and thus is stronger in bending. A strength vs. weight vs. price analysis should be performed to determine the optimal frame size.

p. 14 – Could the back position and seat length be adjusted instead of the wheel position?

p. 16 – Manual says that radial bearings do not work in caser barrels, and that they don't last more than one year. The short bearing life is probably the result of loading the bearings incorrectly with an axial force, and over constraining them with the bearing spacer.

p. 16 – Motivation says they have not worked with cup and cone bearings (also known as angular contact bearings, the kind in bicycle hubs), but they offer a lot of potential.

p. 28 – The manual says that cup and cone bearings should be used in the caster barrel. Sealed bearings will fail under extreme conditions.

p. 28 – A caster angle can be chosen to minimize flutter. This angle should be calculated before friction is added to the caster barrel washer.

KCMC Wheelchair Workshop Business Plan

p. 10 – The target production is 15 to 20 wheelcahirs per month. Both the KCMC and Mobility Care workshops are far below that.

p. 11 – “Funding is sought as a charitable grant rather than an investment loan that must be recouped, to enable the cost of the wheelchairs produced to be kept to a minimum.” Why wouldn’t the workshop run like a true business, and get started with a loan? The cost savings from the initial startup grant would decrease over time.

p. 20 – Manual says that 30% of customers will be able to fully pay for a wheelchair themselves, or have their company pay for it. This figure is much too high. Only 13% of the interviewees in the assessment purchased their own mobility aid.

p. 29 – Outsourcing some manufacturing processes could save a considerable amount in startup costs. Almost $5,000US is consumed by purchasing a lathe, compressor, and spray gun. It might take decades to recoup the cost of these pieces of equipment.

p. 36 – Wheelchair costing should include a more detailed cost breakdown.

Mathematics and Mechanics

This manual needs to be proof-read. There were many small mistakes that can be easily changed. Ex) p. 70, where g is called the gas constant instead of gravitational constant. There should also be continuity in variable usage. G is used as both the gravitational constant and the center of gravity.

p. 69 – Figure 4.8A shows a Free Body Diagram (FBD). The center of gravit (CG) of the person and wheelchair have already been located. How does this teach people how to find the CG of a wheelchair? Technicians need to know how to find the CG in order to make a FBD and calculate stresses.

p. 104 – The forces section should have more breaks between examples. The section is a bit hard to follow.

General note: There are no practice problems where the students have to draw their own FBDs. The students are never made to determine the forces and moments acting on the wheelchair. If the students can calculate forces and moments, then they can easily calculate the stresses in the wheelchair and predict failure points.

Material Technology

Ferrous Metals Section: There is no discussion of treatment processes that affect material properties, such as cold working, hot working, quenching, heat treatment, etc. There is also no discussion about stress, and how it relates to deformation by the modulus of elasticity.

There is no mention of welding weakening a material by relieving residual stresses or changing grain size.

p. 13 – Only the ultimate strength, UTS, is mentioned. UTS should not be used in designs because it is the stress at fracture. The yield stress should be the maximum stress used in calculations.

www.matweb.com has information on almost any material in existence.

p. 49 – No equations for tensile or compressive strength, which should be called stress. Also no equations for bending stress.

p. 50 – there is no mention that the axial yield strength is usually twice the yield strength in shear.

p. 54 – The manual alludes to choosing the highest or most appropriate moment of inertia (same as second moment of area). Instead the manual recommends choosing the cross-section which lowers stress most. If students had an understanding of mechanical behavior, they could understand that increasing the cross-section increases the second moment of area, which lowers stress.

p. 60-64 – Powerdercoating is not mentioned or explained.

Technical Drawing

The WTTC course outline reports that 90/110 hours or the engineering science curriculum and 60% of the engineering science exam is devoted to technical drawing.

Why is there so much time spent on technical drawing if the students are given plans for the three wheelchair models they will build in their own workshops? Why are the students taught so much more about how to draw than how to design?

Technical drawing skills are much less important than having a fundamental understanding of whatever is being drawn.

Some of the technical drawing hours could be replace with lessons on mechanical design.

References

[1] Disability KaR. 10 June 2005 <www.disabilitykar.net>

[2] Conversations with CHAWATA

[3] Tanzania Training Center for Orthopeic Technologies. 20 Apr. 2005 <http://www.kcmc.ac.tz/TATCOT/>

[4] Motivation – the international disability charity. 10 May. 2005 <http://www.motivation.org.uk/>

[5] Whirlwind Wheelchair International. 18 Apr. 2005 <www.whirlwindwheelchairs.org>

[6] "Statistics on Tanzania." 2003. UNICEF. 10 Aug. 2005 <http://www.unicef.org/infobycountry/tanzania_statistics.html>

[7] "Statistics on Tanzania." 2003. UNICEF. 10 Aug. 2005 <http://www.unicef.org/infobycountry/tanzania_statistics.html>

[8] Wheelchair Foundation. 30 Jul. 2005 <http://wheelchairfoundation.org/>

[9] Shigley, J.E. Mechanical Engineering Design. New York: McGraw Hill, 1986.

[10] Email correspondence with Approtech