SPORTS WHEELCHAIR PROJECT
HRS 2709, SPRING 2004

By: Stephanie Martin, Erica Authier, Beth Kaminski, Rachel Cowan, Carol Goepferich, Ana Allegretti, Jennifer Mercer, Ian Rice, Michelle Tolerico, Nethravathi Tharakeshwarappa, Jon Pearlman

Current website: \\Herl03\share\Students\Jon P\HRS2709\WebPage\index.html

OVERVIEW OF PROJECT
Wheelchair Design Goals

1.Removable antitippers
2. Adjustable tension backrest
3. 24" wheels
4. Adjustable seat dump (0 - 15 degrees)
5. Variable camber (0 - 10 degrees)
6. 4" Casters
7. Fore-aft axle position
8. Removable bumpers
9. Height adjustable footrest
10. Four wheels
11. Single anti-tipper (pivot)
12. Cost less than $125 without wheels
13. 16" seat width
14. 16" backrest height
15. Nylon seat upholstery (quickie type)

Management Plan

Literature Search: Jon, Jen, Michelle
Reference Compilation: **Rachel**, Anna
Drawing: **Nethra**, Jon, Erica, Michelle
Manufacturing: **Beth Ann**, Jon, Erica, Michelle, Steph, Nethra
Documentation, Part Inventory, Cost Analysis: **Ian**, Jen
Website: Erica
*names in bold are task managers

DELIVERABLES

LITERATURE REVIEW
Wheelchairs and Developing Nations: An Overview

Abstract

Individuals with mobility impairments in western societies have historically had greater access to mobility devices. Unfortunately, 75% of individuals with disabilities reside in developing countries where access is limited. It has been estimated that anywhere from 20-130 million individuals in developing countries are in need of a wheelchair. For these individuals, wheelchairs are provided through donations and local manufacturing. Although donation constitutes the largest portion of the supply, such chairs often fail to meet the demands of the user and environment. Major failures occur within several months and are difficult to repair for a variety of reasons. Locally produced wheelchairs are more likely to meet the requirements of the user and environment. Furthermore, such chairs are more easily and quickly repaired. Recently, there has been an effort to provide athletic opportunities to residents of developing countries who have mobility impairments. Such efforts legitimize a person's inherent desire to participate and compete in athletic events, without discriminating between the disabled and non-disabled.

Epidemiology

Approximately 10% of the world's population is considered to have a disability, of which 75% reside in developing countries, which generally includes Africa, much of Asia, South America, and the Caribbean (9,33). Many of these people are in need of wheelchairs. Without a wheelchair, a person with impaired mobility is forced to rely on family and friends in order to get around. Some individuals are only able to crawl for their mode of ambulation or they may even be confined to lie in a bed for years at a time (12); (20). Individuals with moderate disabilities can ride hand-propelled tricycles for intermediate distances, but tricycles are too large for indoor use (31). Limited mobility, especially in developing countries, prevents people from taking advantage of opportunities in education, healthcare, and employment. They become more impoverished and further separated from society. In some cultures, people with disabilities are considered a drain on already limited resources. Mobility is a basic need that must be satisfied in order for people with disabilities to fully participate in society and consequently gain equal stature with the rest of the population (20).

Currently, there is no accurate way to determine the need for wheelchairs in developing countries. Some groups have reported that 20 million people in developing countries need wheelchairs (28,34), while others have estimated this number to be as high as 100-130 million people (12). Surely the prevalence of individuals with mobility impairments will expand as the World's population grows. One group has used the disability rate in the United States and applied it to the populations of developing countries. However, this number is probably a huge underestimation due to the environment in developing countries (40). Typically, people may need to use a wheelchair because of inhibited mobility resulting from accidents, birth defects, war injuries, debilitating diseases, or advanced age. In developing countries war injuries, landmine incidences, birth defects, and diseases such as polio are more common than in the United States. Also, medical care may not be as available or as advanced. For these reasons, the disability rate in the United States probably does not directly translate to other countries. Some groups make assumptions and predict a higher need for wheelchairs, such as 100-130 million people, based on this reasoning. Only 1% of people in developing countries who need a wheelchair actually have access to such a device (11,39). The main barrier to access is cost. In many countries, locally made wheelchairs cost three times the average monthly wage (11). Some organizations such as the Wheelchair Foundation (15) and Whirlwind Wheelchair International (WWI) (1) have designed low cost wheelchairs to help meet the need for wheelchairs in developing countries. WWI focuses on starting wheelchair workshops in developing countries so that they can design, build, and repair their own wheelchairs. A similar approach is taken by Motivation (38). Unfortunately, despite the efforts of these organizations, the demand for wheelchairs still far exceeds the supply.

Even if a person does have a wheelchair, the wheelchair is in all probability not of high quality. (25,34). In other words, the wheelchair is not designed for use on rocky, uneven, unpaved terrain as is common in developing countries. According to the World Bank Group, in 1998, only 14% of all roads in the least developed countries were paved (8). As a result, some parts of the wheelchair will break very quickly. The wheelchair is most likely heavy and too wide to fit through narrow doorways. If the chair needs to be repaired, the parts often cannot be found locally, making the repair very expensive. (27) Often the wheelchair is inappropriately fitted or improperly designed for the person's functional limitations. (25) An effort needs to be made to design wheelchairs that can survive the rough outdoor terrain while still being maneuverable indoors. These wheelchairs need to provide some adjustments in order to best accommodate an individual's disability. Thus, one of the important factors when considering wheelchairs for developing nations is whether they are *appropriate* for the environment and culture of the target country.

Mechanisms of Delivery

Since the demand for wheelchairs in developing countries is so large, "Western" nations have devised two methods of delivering as many wheelchairs as possible to individuals with mobility impairments. Donation of wheelchairs is the method most commonly employed to provide individuals with the chance to participate in the community and become more independent. A secondary method facilitates development of self-sustaining local workshops to manufacture and repair wheelchairs. Additionally, individuals within some countries have also independently set up their own systems for manufacturing wheelchairs.

Historically, donation is the most widely utilized method for providing wheelchairs to individuals in developing countries. There are several organizations that have emerged over the last decade that deliver wheelchairs to individuals around the world. Some of these include Wheelchair Foundation, Wheels for the World, Hope Haven, and Wheels for Humanity. The latter three organizations use a similar process to distribute used wheelchairs, whereas the Wheelchair Foundation distributes new wheelchairs in a different manner. Initially, the latter three organizations hold community-wide collection drives in various cities around the United States (5). Once the used wheelchairs are collected, they are then cleaned and refurbished by volunteers. Some of the wheelchairs simply need a thorough cleaning, while others need to be stripped down and rebuilt because they are missing a number of different parts or have damaged parts (35,41). Common parts that often need replacing include wheels, casters, and backrests (35). Wheels for the World and Hope Haven have developed relationships with correctional facilities, where inmates volunteer their time repairing and restoring the wheelchairs (5) (16). Distribution is the next step in the process. The wheelchairs are shipped overseas to a second tier of volunteers. These volunteers usually consist of occupational and physical therapist or other individuals qualified to custom fit wheelchairs (17). Some organizations also provide training on how to maintain and repair the wheelchairs. Each organization has a different process for selecting individuals who are eligible to receive donated wheelchairs, although each group generally uses local organizations and governments to identify individuals in need (5), (23).

The Wheelchair Foundation, founded in 2000, has a different approach to delivering its wheelchairs. It purchases new wheelchairs in bulk from several manufacturers in China and provides these wheelchairs for approximately $150 dollars per wheelchair. The wheelchairs are then distributed through an established network of non-governmental organizations who participate in humanitarian relief missions (6). These organizations manage all aspects of the distribution process. To begin the distribution process, the purchased wheelchairs are shipped to the specific destination via ocean freight containers, which hold 280 wheelchairs. The established distributing organization is then responsible for clearing all of the wheelchairs through customs along with paying the associated fees (14). The next step is for the organization to identify and screen possible recipients to determine if they meet the two donation criteria, which include the need and inability to purchase a wheelchair. A donation ceremony is also planned, thus recognizing both donors and recipients. After the wheelchairs have been distributed, photographs are taken of every individual seated in their new wheelchair and sent back to the Wheelchair Foundation (14).

Thus far, the Wheelchair Foundation has delivered or committed 225,614 wheelchairs to individuals in 120 countries (13), by far the largest quantity of any organization. However, Hope Haven's International Ministries have donated over 38,000 wheelchairs to over 90 countries since its beginning in 1994 (16). Through the year 2003, Wheels of the World had delivered over 20,000 wheelchairs to over 60 countries (18). Over a seven-year span, beginning in 1996, Wheels for Humanity has delivered 12,000 wheelchairs to individuals around the world (2).

Although the wheelchair donations are greatly appreciated by the individuals in the developing countries, these devices are not always the most appropriate solution for each individual. In a majority of the cases, when delivering the wheelchairs, the primary focus is on the mobility device and not on the end user. Individuals most often receive wheelchairs that do not fit their needs (age, size, physical condition, goals, etc). Therefore, the wheelchair does not increase their mobility, independence, or ability to become integrated into society (37). Also, since most of the donations are discarded or used wheelchairs from industrialized countries, the different environmental situations of the developing nations were not taken into consideration when the wheelchair was designed.

Figure 1: Huckstep Chair

While standard style chairs improve the ability of persons with disabilities to move around inside their homes, they are usually ineffective in outdoor travel especially across slopes on crumbling, craggy rock and mud roads. The International Standards Organization (ISO) has developed standards for fatigue life of wheelchairs that specify a wheelchair should last 3-5 years of typical wheelchair use. Studies have shown that most standard wheelchair fail to meet the ISO fatigue criteria (22) Hence, it is no surprise that massive structural failures often occur with 6 months of usage in more rugged, demanding environments. Ineffective brakes, fractured frames, broken axles, broken caster forks, busted footrests, rapidly loosening spokes and chronic bearing failures are common to standard wheelchairs (29). In the event of failure, obtaining replacement parts is virtually impossible because of they are typically unavailable to purchase locally, and prohibitively expensive to import. Donated wheelchairs usually do not optimize an individual's ability and function and tend to fail quickly, making them a short-term solution to the problem at hand. Another issue that arises with the donation of wheelchair is the negative impact on local wheelchair manufacturers due to a decrease in demand (37), (34).

A second mechanism of wheelchair delivery used is setting up local manufacturing workshops in developing countries. The first project to develop a locally built wheelchair occurred in Uganda in 1967, and was the design of orthopedic surgeon Dr. Ronald L. Huckstep. His design was made from old chair frames and bicycle parts. This was the first durable tubular wheelchair built in a developing country (Figure 1). The cost of the materials varied between US $50 and $100. By 1975, more than 1000 had been produced (36). He published a manual called "Simple Wheelchairs and other Vehicles" in 1975. Huckstep fabricated his chairs from broken metal frame chairs. These were welded and a supporting frame was added for the bicycle wheels. Canvas seats and backs were prepared from old canvas mail bags. Old hospital carts were scavenged for caster wheels. The three-wheel design has 2 large wheels in the front and a third caster wheel trailing in the center back (31).

Figure 2: Zimbabwe Chair

Since 1980, Whirlwind Wheelchair International (WWI) (formerly the Wheeled Mobility Center) headed by Ralf Hotchkiss has promoted local manufacturing to ensure that the wheelchair is appropriately designed as well as low in cost. Wheelchair users and mechanics in Nicaragua developed the original Whirlwind wheelchair in 1980. Since then their counterparts in California have trained more than 150 mechanics in the fabrication of the whirlwind wheelchair and more than 25 small scale manufacturing workshops in 20 different countries have been established (25).
(30), (25), (29). The cost of a Whirlwind wheelchair varies depending on the country of origin. In most locations, the price ranges from US $150 to US $250, but in places like Zimbabwe the wheelchair can cost over US $300 (25).

Whirlwind utilizes innovations in wheelchair design that flowed from users and mechanics around the world. The seats of the Whirlwind are closer to the ground to lower the center of gravity. This makes the chair less susceptible to tipping on rough terrains. The front wheels of the newer models, such as the Afghan Chair, extend farther outwards and are located just below the footrests. This makes the chair longer and decreases the likelihood of tipping forward when the front wheels hit a bump that suddenly stops the chair. Tips and falls are the leading causes of injury for wheelchair users (24) The newer models of the Whirlwind have a unique front wheel named the Zimbabwe Wheel, names and modeled after a push cart in Zimbabwe. The 3 inch wide rubber wheel rolls over almost any dirt path (Figure 2). The larger push wheels are usually mountain tires if the user lives in a rural area. The push wheels are standard treaded tires if the wheelchair is to be used in an urban area. The bald standard wheelchair tires are not recommended. The Whirlwind also has a Jump Seat in the Kenya wheelchair design to assist someone to transfer from the seat to the ground. The Jump Seat is connected to the front bars of the chair, just behind a user's legs. (32)

As noted above, another group providing appropriately designed wheelchairs is Motivation (38), a non-profit organization located in the United Kingdom. Their focus is to provide technical assistance to wheelchair technicians to build better wheelchairs and provide more comprehensive services to their clients. Motivation has worked in Asia, Central America, Africa, and Eastern Europe. They have several wheelchair designs, each targeted for the different cultures and environments of their recipient countries.

Building wheelchairs locally not only ensures a low cost wheelchair, but also ensures designs are developed with the cultural, psychological, and physical environments in mind (34). Manufacturing wheelchairs within developing nations tends to ensure the availability of parts and skilled technicians. Local workshops also provide individuals in the community with employment opportunities, especially individuals with disabilities. The input of these individuals is important because they know what are the most important features necessary for designing a long lasting wheelchair. However, such production is low in volume. In 1990, an incomplete survey of manufacturer's estimates indicated that the developing country wheelchair production may be in the neighborhood of 50,000 units per year (26). Thus, it is unlikely that local production can supply the volume of wheelchairs needed by those with mobility impairments.

Another approach to local wheelchair manufacturing and distribution is large-scale indigenous manufacturing. The unique example of this is the Artificial Limbs Manufacturing Corporation of India (ALIMCO) (19). As the largest assistive technology (AT) manufacturing plant in south Asia, ALIMCO manufactured over 11 million AT devices in 2003, including over 15,000 wheelchairs. With financing from the Indian government, ALIMCO has been able to and will continue to expand its production capability and is slowly improving their designs to be more appropriate for the Indian terrain. ALIMCO has established satellite manufacturing and distribution points inside India and Afghanistan to fit and distribute prosthesis. This infrastructure may prove to be effective in providing a large number of appropriate wheelchairs to persons with disabilities in India and Afghanistan. Furthermore, it may be a useful model to utilize when establishing other wheelchair manufacturing, fitting, and distribution companies around the developing world.

Sports Wheelchairs

Importantly, the primary concern of individuals with mobility impairments is the attainment of basic mobility. However, the desire to participate in recreation and athletic competition is still present, yet often unfulfilled. Thus, the next step is to provide opportunities and equipment to facilitate the development of athletic competition in developing countries among individuals with disabilities. Such efforts are being made by several small organizations, with the largest scale projects being advocated by the International Paralympic Committee (IPC). This organization held the first International Paralympic Day in Bonn, Germany in September of 2003 to promote the inclusion of sport into the lives of those with a disability. This two-day event included fencing, rugby, basketball, and skiing for participants. Its motto, Integration Through Sport, was held to high regard. The overall intent was to express “the importance of sport as a means to integrate people with a disability, the work of the IPC as the worldwide organization promoting sport for athletes with a disability, and the variety and excellence of Paralympic sport.” (7)

In preparation for the 2004 Paralympic games in Athens and to enhance the membership of the National Paralympic Committees, the IPC in conjunction with the Dutch National Paralympic Committee and the Recreational Sports Development and Stimulation Organization have initiated a project to stimulate participation among new nations. This project, ATHENS 2004 Paralympic Games Special Initiative, is intended to encourage Cape Verde, Ethiopia, Ghana, India, Kenya, Pakistan, Rwanda, Tanzania and Uganda to send delegates to the Athens 2004 Paralympics. Included are instructional seminars for athletes, coaches, and administrators to develop their skills and their National Paralympic Committee (10). In addition, IPC is currently working to fund other projects in 2004, including development of IPC Accredited Sports Technical and Classification Courses for the Asian Paralympic Committee and a Classification Clinic for Athletes with Physical Disabilities in the Americas Paralympic Committee (4).

The International Paralympic Committee publishes a quarterly newsletter, *The Paralympian*, which highlights recent events and happenings in the world, relating to the world of disability sports. The mere assembly of this information can be seen as a step to further the advancement and organization of sports in the world, and in developing countries in particular. The most recent issue discussed the International Blind Sports Association’s annual conference for the Asia and Oceania division and their intent to employ new strategies for the promotion of sport in this region of the world. One of these strategies, which can and hopefully will be applied to other disabilities and developing areas, is the proposition of organizing a series of sports-specific technical seminars in Asia and Oceania, with expertise provided by IBSA technicians (21). Other recent events include the 8^{th} All-Africa Games (3) and their impact on the development of sports throughout most of the nations of Africa, with a special division for sports for the disabled.

The need for wheelchairs appropriate to the environment of developing countries is apparent. Not only must the wheelchair be functional for the individual’s mobility needs, it must be suitable in their environment. We go above and beyond these needs, incorporating the ongoing attempts to advance sports and health in these nations by including features appropriate to sport participation. Our hopes for the future are that our small contribution of a sports wheelchair may help advance the process of training athletes and therefore promoting the development of sport in developing nations.

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MANUFACTURING INSTRUCTIONS

Parts to Manufacture and their components

A) Side Frames (2)
- top bent rail
- axle rail
- seat-back uprights
- seat-bottom pivot tubes

B) Seat Bottom
- Side tubes (2)
- Front tube
- Back tube
- Back flat-bar fasteners (2)

C) Axle (2)
- Outer tube (0 and 10 degree camber)
- Axle nut insert tubes (2/axle)
- Axle nuts (4/axle)

D) Back anti-tipper
- Bent tube
- Caster wheel/fork
- Caster bearing housing
- Outer socket tubes (to slide over frame rails)

E) Front caster-tube
- Cross-tube
- Caster wheels/forks (2)
- Caster bearing housing (2)

F) Axle-rail/axle fastener (2)

G) Foot peg
- Upright receivers (2)
- Peg tubes (2)
- Foot platform

H) Miscellaneous Parts & Procedures

Note, number of pieces for above list is *one* unless otherwise noted in (parentheses)

Tools Needed:

Drill press, drills (1/16" up to 1.25")
Oxy-acetylene torch with welding tip and brazing rod
Tubing cutter (largest tube is 1 ¼ inch)
Screwdrivers
Hammer
Cutoff saw
Tubing Bender
Simple Wood Jigs (See photos below)

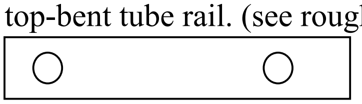
Grinder with grinding wheel
Belt Sander
Pliers
Flat-bar Bending Jig
Tap set (10-24)
Hand Drill
Band saw
Allen hex wrenches

This instruction manual should be used with detailed, dimensioned drawings of parts.

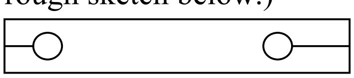
(A) Side Frames

1) Cut top-bent tube long
2) Mark location of beginning of bend, and bend to specified angle
3) Cut bird's mouth at front-end of top-bent tube, or use procedure described below (drill ¾ in hole, and bend out web) to support front-caster tube.
4) Cut front caster-tube receiver (1" ID)

5) Cut axle rail to specified length (longest portion on drawing)
6) Drill 2 3/4" holes at each end of tube through only *one* side of the tube. These holes reference the shortest portion of the tube (top, in assembled side-frame) which contacts the top-bent tube. They should be placed at the same radial angle as each other, and spaced in from the end so they cut out a portion of the tube that will ultimately intersect the top bent tube. The location of the center of the drill hole will be 3/8" (the radius of the ¾" drill) *less* than the distance where you would cut a wedge out of the axle rail to fit into the bend of the top-bent tube rail. (see rough sketch below)



7) Using the cutoff-saw, slit from each end of the axle rail tube to the ¾ in hole drilled (see rough sketch below.)

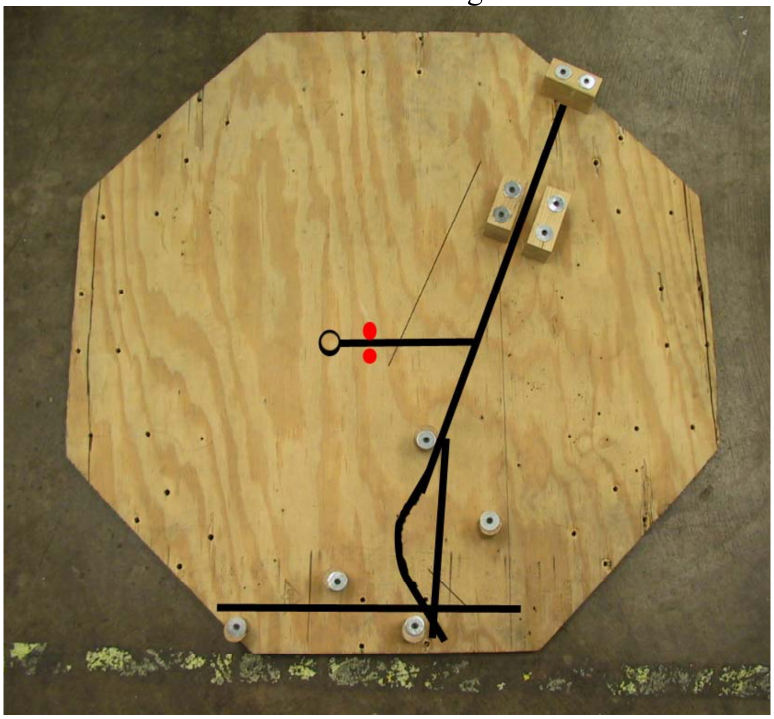


8) Using a screwdriver and pliers, bend open each end of the tube until the end is in the shape of a channel (see rough sketch looking from end below). After opening up the ends of the tube, confirm it slides onto the top-bent tube; use pliers to adjust as necessary. After bending is complete, use grinder or belt sander to round sharp edges (see rough sketch of tube with web bent out below) .

9) Cut seat-bottom pivot tubes from stock, adding 1" to specified longest length on drawing
10) As done above in the axle rail drill ¾" holes, this time all the way though the tube. Also, in this case, the holes should be perpendicular to each other and the bottom hole should be at the specified angle of the intersection with the top-bent tube. The holes should be spaced so the measurement from the inside-to-inside of each hole matches the dimensioned drawings.

11) Using the cut-off saw, slit both ends of the tube along the appropriate radial angle to intersect with the center of each hole
12) Using a screwdriver and pliers open each web at each end of the tube. As above, place ends over bent-top tube to assure fit. Use grinder or belt-sander to round sharp edges.
13) Cut stock for actual pivot point for seat (1" ID). Make sure top-end (with hole perpendicular to tube axis) of pivot tube fits snugly around stock…adjust pivot tube with pliers as necessary.
14) Cut stock for seat-back tubes to specified length on drawings.
15) Repeat 1-14 for second side.
16) Assemble both side-rails in jig using all pieces except seat-back tubes. Each side-rail and associated components should be put in the jig together and secured together to assure matching and symmetry.
17) Tack-weld each joint
18) Remove side-rails from jig, and complete welding
19) Place one side-rail back in jig, and position seat-back tube and secure with jig-fixtures
20) Tack and weld seat-back tube, and be sure to not change jig-fixtures.
21) Place second side-rail in jig and place seat-back tube in previously locked jig fixtures, making sure seat-back tube is on opposite side of side-rail. Thus, make sure you are making a mirror image of the first side-rail, not a copy.
22) Tack and weld seat-back tube.

Side Frame Jig



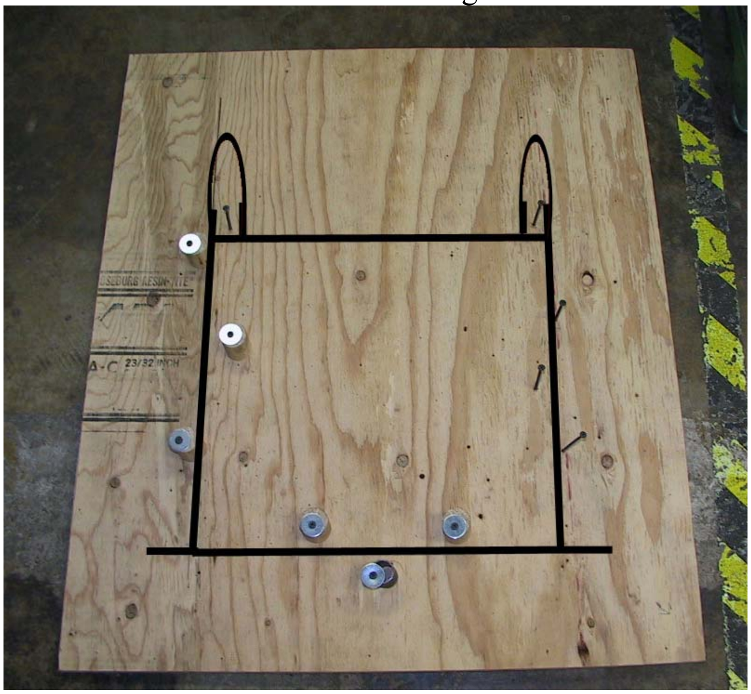
(B) Seat Bottom

1) Cut all tubes to specified length
2) Cut flat-bar to specified length
3) Use chop-saw to cut slit in middle of flat-bar starting and ending 1" from each end

4) Using flat-bar bending jig, and hammer—or arbor press, if available—bend flat-bar to form large U.

5) Place all pieces in seat-bottom jig and tack all joints.
6) Take seat-bottom out of jig and complete welding.

Seat Bottom Jig



(C) Axle

1) Cut stock to specified length
2) Bend desired camber using tubing bender. Be sure to start bend in correct place so center of axle will correspond to center of bend
3) Cut axle-nut insert tubes (1 ½ inch long)
4) Using a belt-sander or grinder (or lathe, if available) reduce the outer diameter of the nuts by rounding out the edges of the hex.   Do this uniformly until the nuts slip snugly inside the axle-nut insert tubes.
5) Repeat with all nuts.
6) With two nuts on an axle bolt, slide into axle-nut insert tubes. Adjust nuts on the bolt so 1/3 of each nut sticks outside of the axle-nut insert tubes.
7) Weld each nut to the axle-insert tube

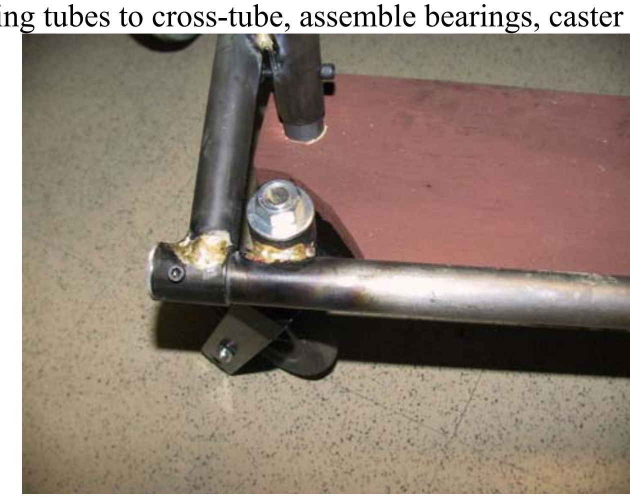
8) Remove excess weld with grinder or belt-sander
9) With axle-bolt still screwed into axle nuts and insert tube, slide into one end of the axle. Keep ¼" of the axle-nut insert-tube sticking outside the end of the axle, and weld.
10) Repeat 6-9 for other side of axle.

(D) Back Anti-tipper

1) Cut bent-tube to specified length
2) Bend ends of tube at specified location to 90 degrees
3) Cut notch on inside of bent-tube at specified angle to the bends (45 degrees). This can be done in several ways. Ideally, a mill can be used with a 1 ¼ end-mill. Other ways include cutting a notch with a hack-saw or cutoff-saw (very carefully). A skilled welder can also cut this notch with a cutting tip. If a notch cannot be made easily, consider adding a gusset to support the bearing housing tube.
4) Cut bearing housing tube to specified length
5) Bore out each end of the bearing housing tube to allow snug fit or bearings. This can be done with a 1" drill or counter-bore. Be sure to drill into tube only enough for bearing to slide completely in the tube. If drilled too far, or for extra strengths, consider indenting the tube with the tubing cutter with a rounded roller (not the cutting roller).
6) Cut outer socket tubes to specified length.
7) Weld outer socket tubes and bearing housing tube to bent anti-tipper tube. Add gussets if needed.
8) Assemble caster bearings, casters forks, and caster.

(E) Front Caster-tube

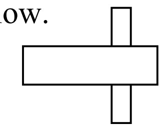
1) Cut cross-tube to specified length
2) Cut notches in cross-tube with techniques described in (D3) or use gussets to support bearing housing tubes.
3) Cut bearing housing tubes and prepare for bearings as described in (D5)
4) Weld bearing housing tubes to cross-tube, assemble bearings, caster forks, and casters.



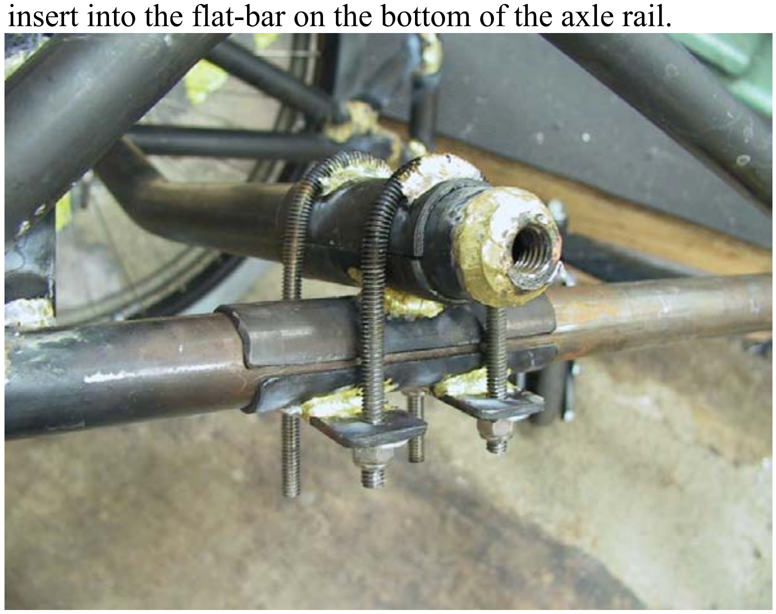
(F) Axle-rail /axle fastener

1) Cut two pieces of tube, one with 1" ID and one with 1 1/8 ID to specified length (3-4").

2) Using cuttoff-saw, band saw, or hack saw, split both tubes, and set one set (half small and large tubes) aside.
3) Weld the remaining tubes in the following cross orientation:
   Long-axes of the tubes perpendicular
   Rounded parts of each tube touching and tangent
   Larger radius tube touching the midpoint of the smaller radius tube
   Larger radius tube midpoint offset from smaller radius midpoint by 1"
   A rough sketch is shown below.



4) Cut flat-bar to specified length, and drill ¼ holes where specified.
5) Cut ¼-20 all-thread to specified length
6) Bend all-thread around 1 ¼ pipe to make u-bolts
7) Assemble chair, and put welded portion of the fastener between the axle (larger radius side) and the axle-rail (smaller radius side). Be sure that the short portion of the larger radius side is toward the *outside* of the wheelchair. Use other large and small ½ of split tubes to put on top of axle and bottom of axle-rail, respectively. Pass u-bolts on top of the axle, and around the axle-rail to insert into the flat-bar on the bottom of the axle rail.



8) Tighten nuts on u-bolt to clamp the whole system in place.
9) With the fastener clamped in place, tack-weld the u-bolts to the top ½ tube piece places on top of the axle. Also, tack-weld the flat-bar where it touches the bottom ½ tube piece under the axle-rail.
10) Remove tack-welded fastener and complete welding
11) Replace system on assembled chair

(G) Foot Peg

1) Cut two receiver tubes to specified length
2) Cut two peg tubes to length. Drill adjustment holes according to drawing.

3) Cut a piece of plywood to the shape shown in dimensioned drawing for the foot platform. Drill out two holes in wood as described. Insert a peg tubes into the two holes in the platform so they are flush with the wood surface. Place a screw from the side of the wood through the peg tube to lock into place.
4) Weld receiver tubes to side frames (inside).
5) Drill one hole in receiver tubes for adjustment bolt.
6) Insert peg tubes into receivers and pass bolt through hole on both sides of the receiver and peg tubes.

(H) Miscellaneous parts and procedures

Seat Bottom

1) Upholstery can be screwed to the seat bottom with self-tapping, or machine screws. A cushion needs to be added on top of the upholstery.

2) To setup adjustable seat-dump, use goniometer (or approximate) desired seat dump angle. Then mark bolt location (through slot in flat-bar) and drill ¼" hole with hand drill. Repeat for all desired angles (prototype has holes for 0, 10, 15 degree seat dump).

Seat Back

Sling seat-back upholstery across seat-back tubes. Special seating systems can be bolted directly to the tubes if necessary.

Tube plugs

Sharp tubes (at seat-back tubes, seat-bottom pivot, and front-caster tube) can be filled by fitting a piece of plastic or rubber into the tube.

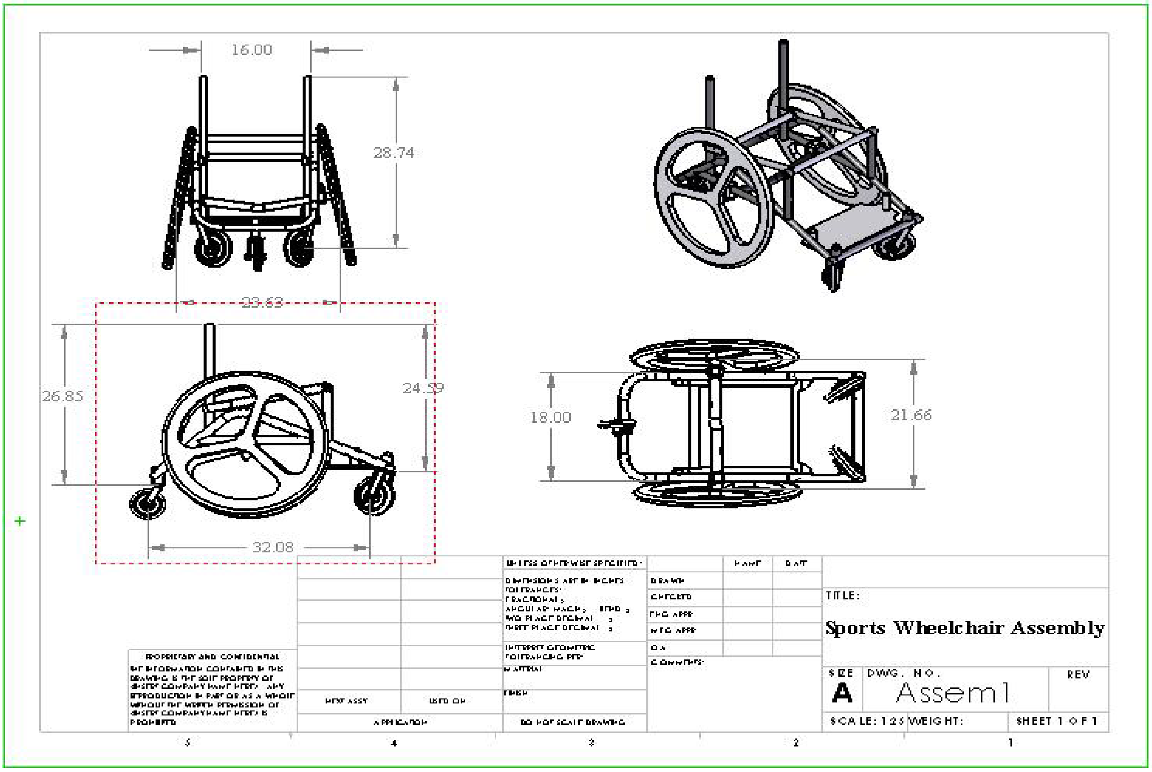
Many methods to can be used: 1) use a lathe to turn down a piece of round-stock to fit a plug into the hole, 2) a grinder can similarly be used to turn down plastic or wood, 3) a router could be used similarly, 4) two pieces (one the ID of the tube, and another the OD of the tube) could be cut and screwed together to form the plug. Note that the plug for the front-caster tube can be made of metal and also act as the locking mechanism (below) for caster adjustment.

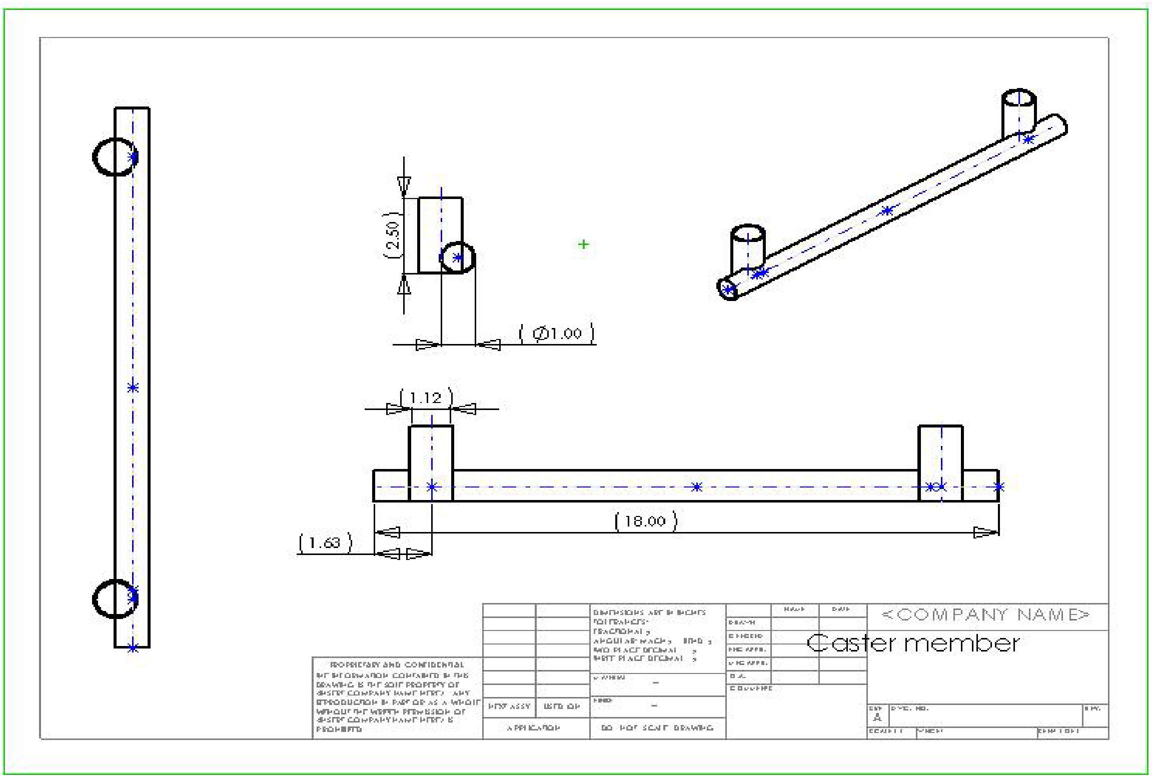
Front Caster-tube locking mechanismAfter the wheelchair has been assembled, the front-caster tube should be rotated so that the caster bearing housing tubes are vertical relative to the ground. To lock this position, and also allow for adjustments (when different axles are used) a locking mechanism needs to be made using the following procedure.

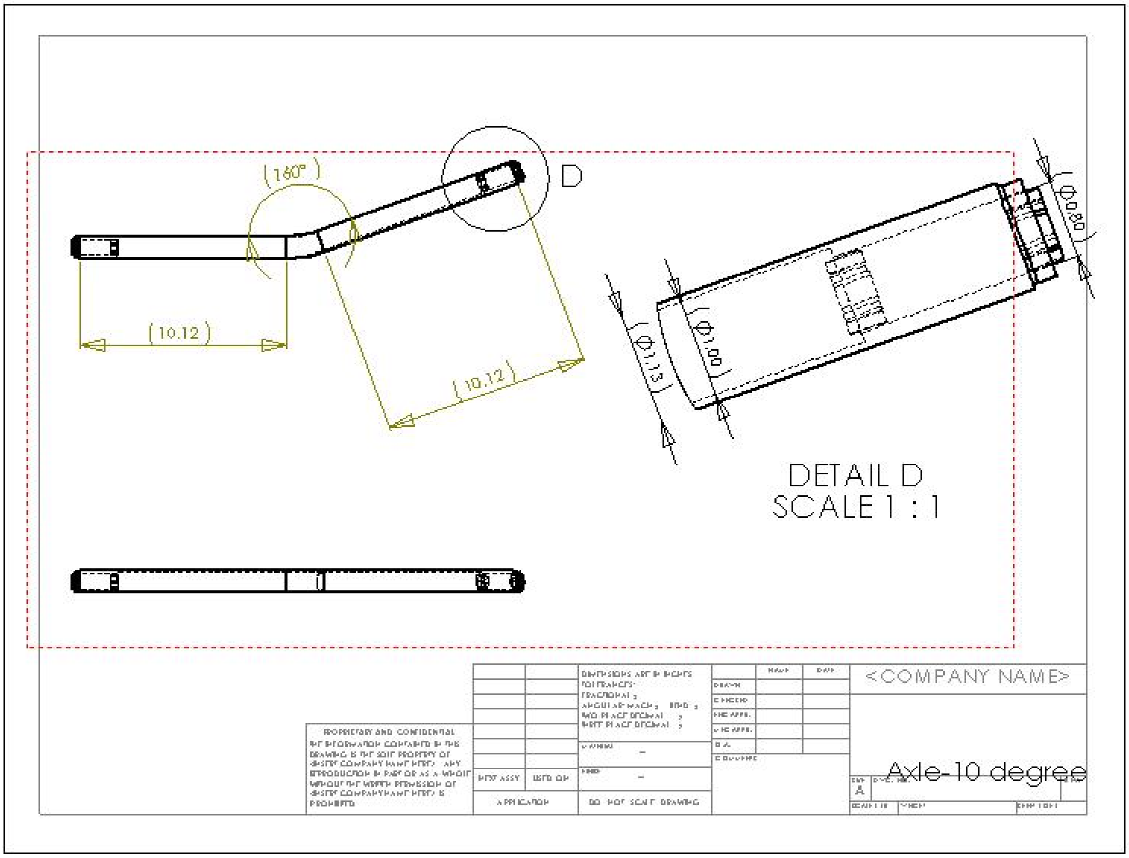
1. With caster bearing housing tubes vertical on assembled chair, drill hole (large enough for 10-24 bolt through each side of the caster tube pivot point) through side-frame portion and caster tube portion on both right and left side of the chair. Drill this hole through only one web of the tube, and locate it in the center of pivot point tube on the side-frame.
2. Remove the caster-tube and open 10-24 hole into a slot around the radial direction. The slot length needs to be only 3/8" long. This will allow for the caster-tube to be rotated to accommodate various axles. This slot can be made in several ways: 1) drill more holes and use a file to connect the holes, 2) Use the cut-off saw to 'slice' part-way through the tube to create the slot, 3) Or, if available, use a milling machine…
3. To lock the caster tube in place, make a metal plug or insert with a 10-24 tapped hole that slips into the caster tube on both ends. To mark this plug, assemble the chair, and slide the un-tapped plug into the tube. Mark where the existing holes are that were drilled in 1) above, and drill and tap the plug.

Final Product

DIMENSIONED DRAWINGS







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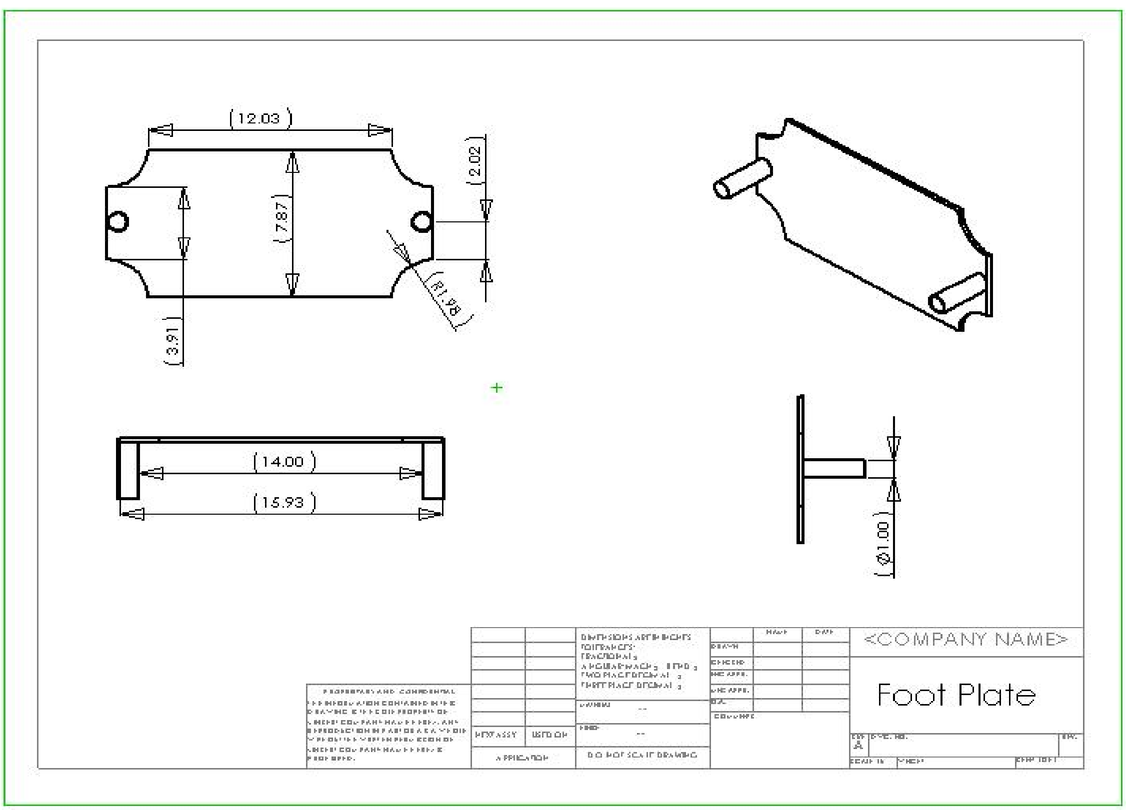

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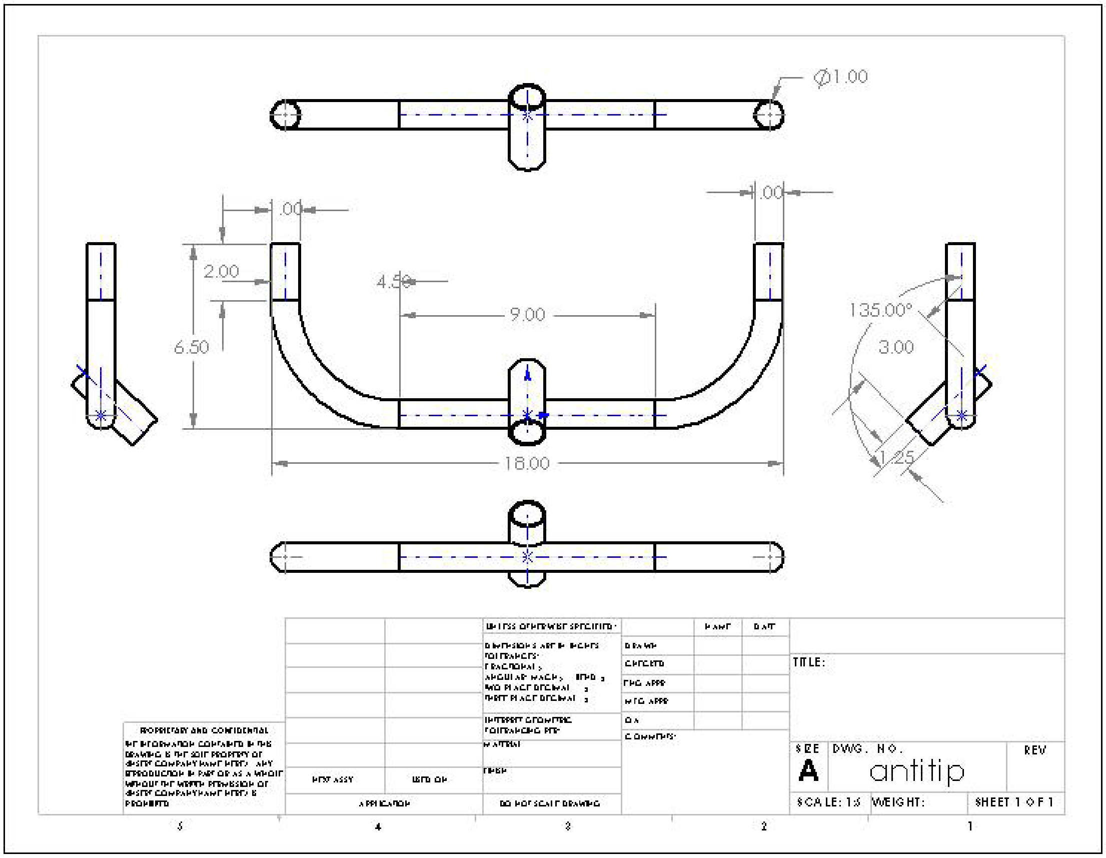

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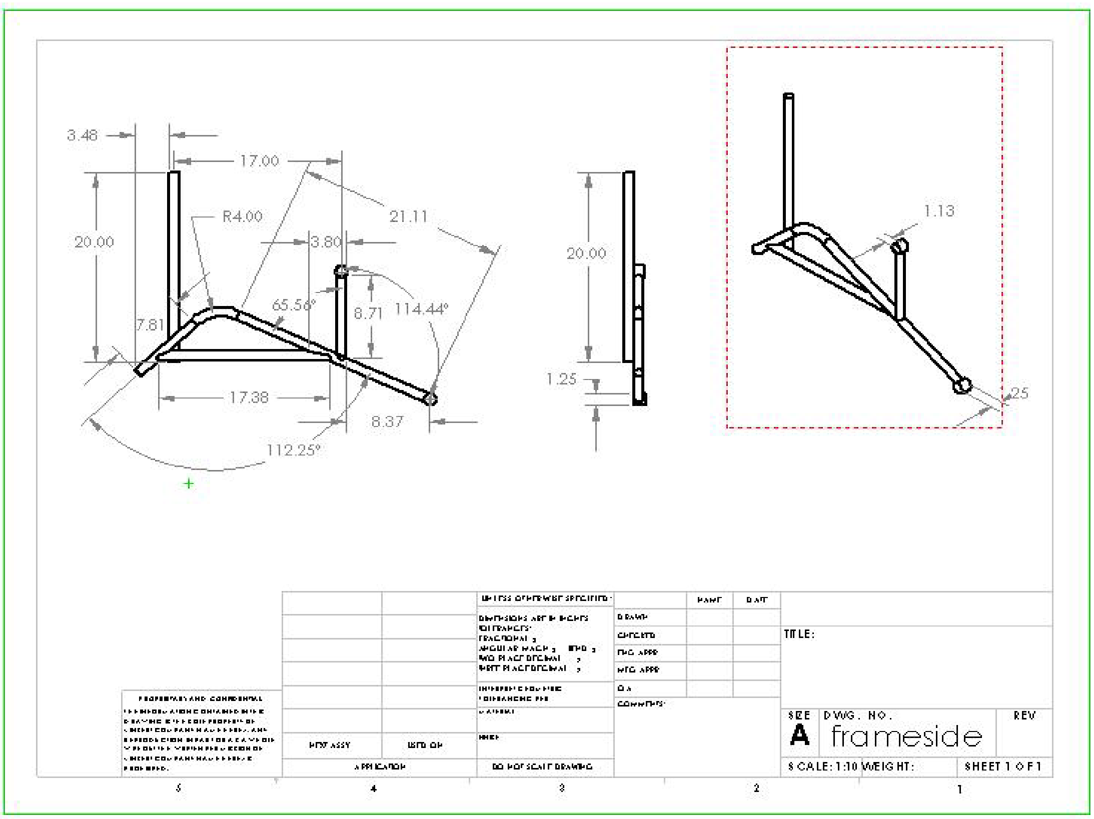

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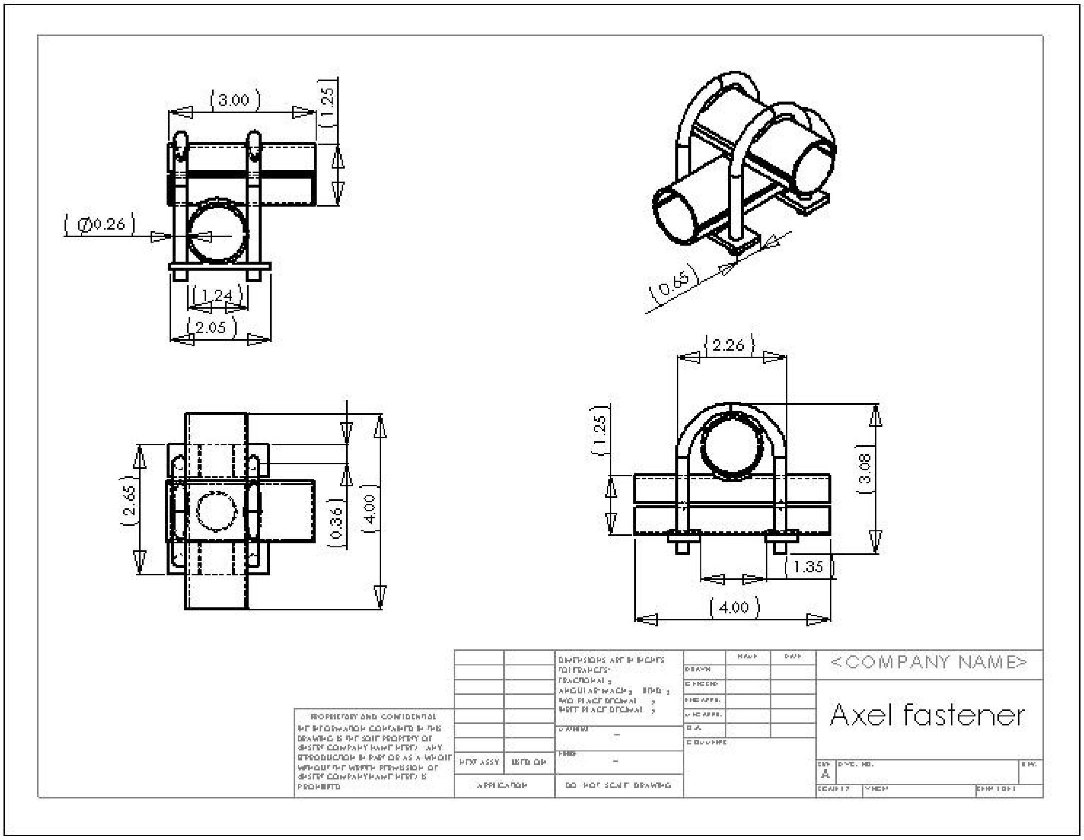

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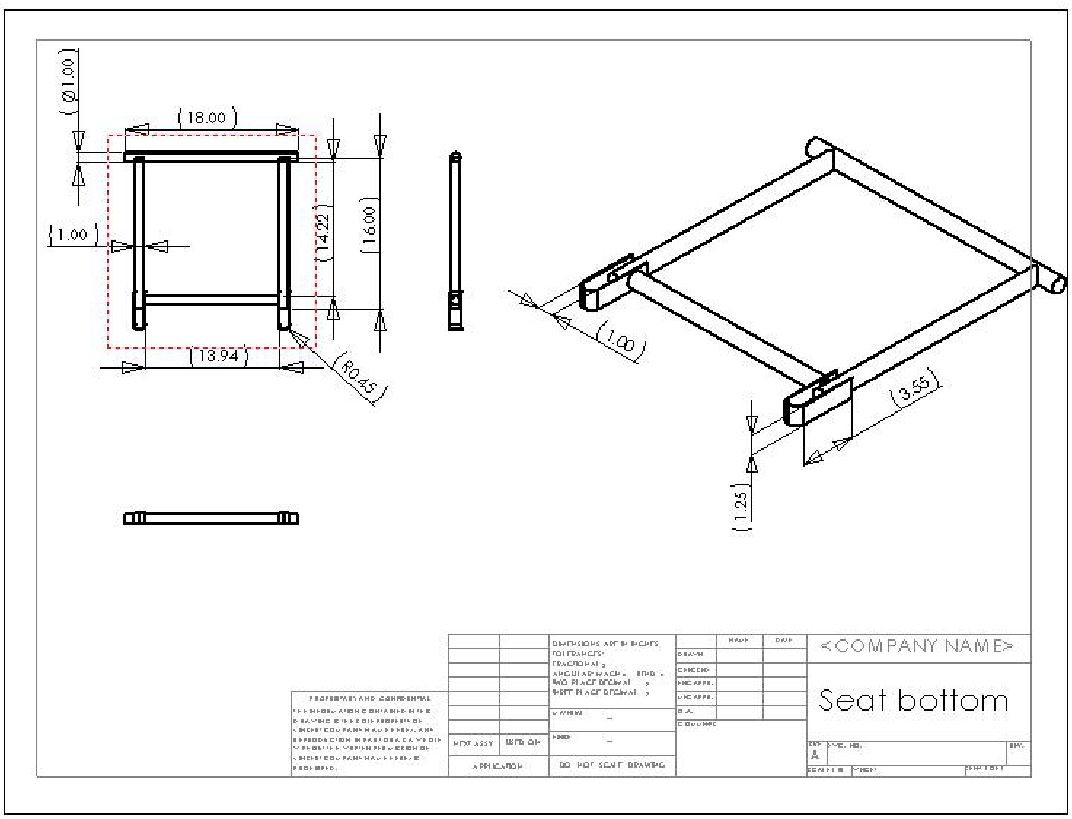

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Seat bottom
PROPRIETARY AND CONFIDENTIAL
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DO NOT SCALE DRAWING

COST ANALYSIS

SPORTS WHEELCHAIR PARTS: COST ANALYSIS

Part	Description	Length (ft) /Quantity	India Unit Cost	India Total Cost	US Unit Cost	US Total Cost
Front Caster Forks		2	$1.50	$3.00	$30.00	$60.00
Antitip Caster Fork		1	$3.00	$3.00	$30.00	$30.00
Axle Tube: 0 degree camber	Mild Steel Tubing, 1.125 OD x 0.65 wall	2' / 1	$0.50/ft	$1.00	$2.82/ft	$5.64
Axle Tube: 10 degrees camber	Mild Steel Tubing, 1.125 OD x 0.65 wall	2' / 1	$0.50/ft	$1.00	$2.82/ft	$5.64
Back Antitip Wheel		1	$2.00	$2.00	$15.00	$15.00
Front Caster Wheel		2	$1.00	$2.00	$12.50	$25.00
Bearings	1.125" OD, 0.5" ID	6	$0.80	$4.80	$5.00	$30.00
Seat upholstery bottom with hardware	nylon sheet	1	$6.00	$6.00	$30.00	$30.00
Seat upholstery back with hardware	nylon sheet	1	$6.00	$6.00	$40.00	$40.00
Axle	0.5" x 4" bolt	2	$0.50/ft	$0.33	$3.00/ft	$6.00
Axle Nuts		8	$0.01	$0.08	$0.50	$4.00
Wheelchair Frame	Mild Steel Tubing, 1 OD x 0.35 Wall	20'	$0.50/ft	$10.00	$2.54/ft	$50.80
Wheelchair Frame	Mild Steel Tubing, 1.25 OD x 0.65 wall	1'	$0.50/ft	$0.50	$2.82/ft	$2.82
Axle to Frame Clamps	1 x 0.125" flat bar	1.5" / 4	$0.50/ft	$0.25	$1.25/ft	$0.66
Axle to Frame Clamps	1/4-20 all thread	2'	$0.50/ft	$1.00	$1.50/ft	$3.00
Seat Bottom Clamps	1 x 0.1875" flat bar	5" / 2	$0.50/ft	$0.42	$1.25/ft	$1.04
Caster Tube to Frame Clamps	1" round stock-steel	2" / 2	$0.50/ft	$0.17	$1.00/ft	$0.33
Brazing Rod for Welding		10 sticks	$0.50	$5.00	$1.00	$10.00
Gas for Welding		1	$2.00	$2.00	$5.00	$5.00
Foot Plate	7" x 18" sheet of 3/4" Plywood	1	$1.00	$1.00	$3.00	$3.00
Miscellaneous Hardware	Nuts, bolt, screws	approx. 20	$2.00	$2.00	$10.00	$10.00

SPORTS WHEELCHAIR: LABOR

	Description	Time	India Labor Rate	India Total Cost	US Labor Rate	US Total Cost
Labor	Time to make and assemble wheelchair	30 hours	$250/mo = $1.56/hr	$46.80	$10.00	$300.00

SPORTS WHEELCHAIR: Total Cost

India Parts Cost	$51.55
India Labor Cost	$46.80
India Total Cost	**$98.35**

US Parts Cost	$337.93
US Labor Cost	$300.00
US Total Cost	$637.93

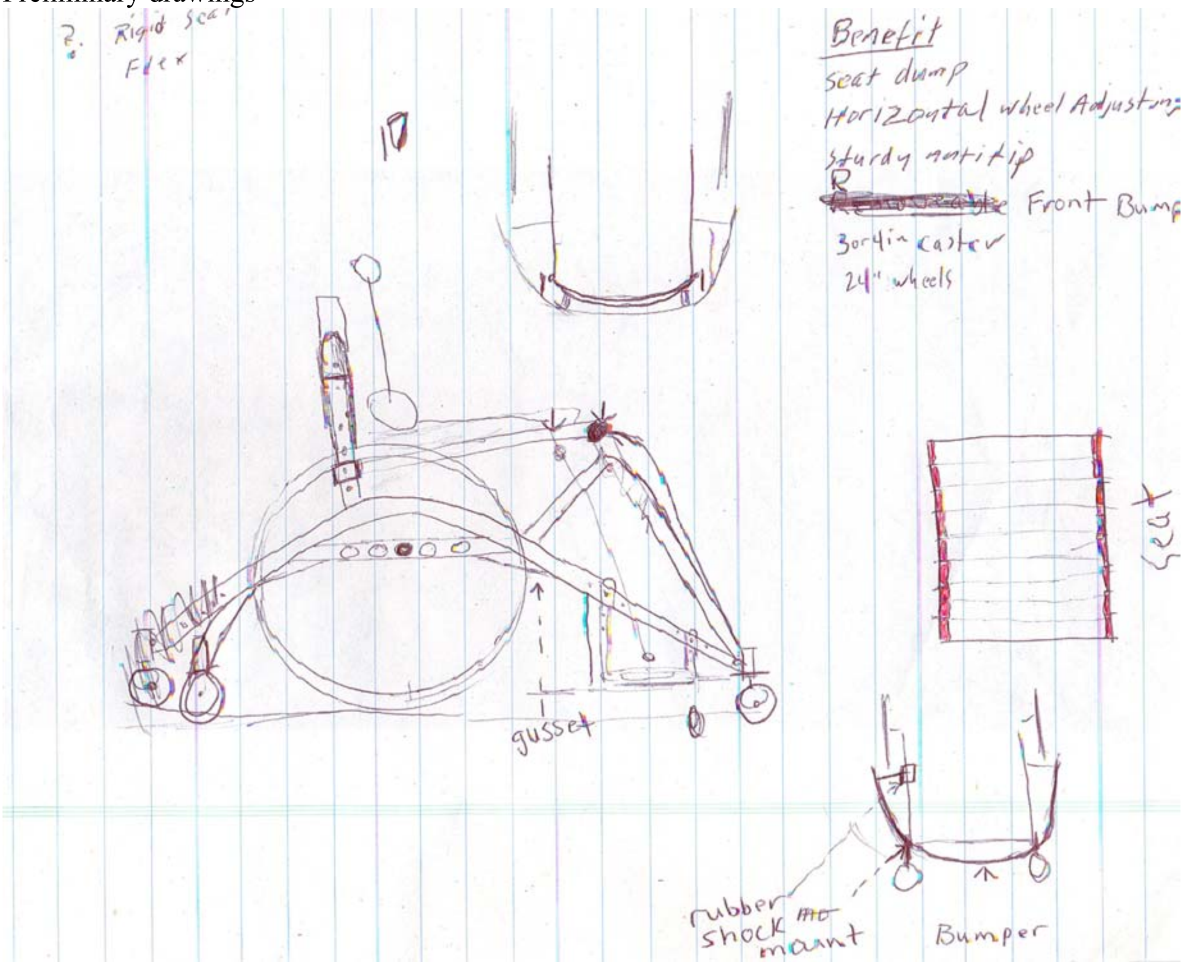
US prices estimated from: http://www.affordableoption.com/conWheelchair.html or http://www.mcmaster.com/
India prices are considered an estimate for developing countries in general.

RAW MATERIALS ORDERED BY HERL

Stock Ordered	Description	Length (ft) /Quantity	India Unit Cost	India Total Cost	US Unit Cost	US Total Cost
td 1.125x.065	Mild Steel Tubing, 1.125 OD x 0.65 wall	10'	$0.50/ft	$5.00	$2.82	$28.20
td 1.25x.065	Mild Steel Tubing, 1.25 OD x 0.65 wall	10'	$0.50/ft	$5.00	$3.50	$35.00
td 1.125x0.120	Mild Steel Tubing, 1.125 OD x 0.120 Wall	10'	$0.50/ft	$5.00	$5.02	$50.20
td 1.00x0.035	Mild Steel Tubing, 1 OD x 0.35 Wall	30'	$0.50/ft	$15.00	$2.54	$76.20

APPENDIX

Preliminary drawings



Correspondence with Rich

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Sounds good!

-----Original Message-----
From: Jon Pearlman [mailto:jlp46@pitt.edu]
Sent: Monday, March 22, 2004 4:15 PM
To: Richard St.Denis
Subject: RE: Sports Wheelchair

Hi Rich,
What I really mean is guards.  We have designed removable guards for the
front to ensure the casters do not get tangled in other people's chairs when
playing sports (basketball, etc.).  And for the small wheels, we have
designed it based on pretty standard, readily available wheels;  swapping
these out for roller blade wheels is trivial (we just put them through lower
holes in the forks), but we did not want to assume it is easy to find them
in other countries.
Thanks,
Jon

________________________________
From: Richard St.Denis [mailto:saintd@peakpeak.com]
Sent: Mon 3/22/2004 5:18 PM
To: Jon Pearlman
Subject: RE: Sports Wheelchair
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It looks good! Just a couple of questions... What do you mean by 'bumpers' and what type of small wheels are you using for the front & back? Typically we use roller blade wheels.

Thanks,
Rich

-----Original Message-----
From: Jon Pearlman [mailto:jlp46@pitt.edu]
Sent: Monday, March 22, 2004 3:04 PM
To: Richard St.Denis
Subject: RE: Sports Wheelchair

Dear Rich,
Sorry to not keep you updated more frequently. We have the design together and are in the middle of building it. It may be a bit hopeful, but I think we can be riding it by this Friday. I've attached an image of the chair design for you to have a look. We have the footrest and bumpers designed, but they are not included in the attached assembly drawing. We also will have two axles, one with camber and another without. Please let me know what your impression of the chair is.

Regards,
Jon
-----Original Message-----
From: Richard St.Denis [mailto:saintd@peakpeak.com]
Sent: Monday, March 22, 2004 3:49 PM
To: Jon Pearlman
Subject: RE: Sports Wheelchair

Jon,
Just checking to see how you're doing with the wheelchair design.
Richard St.Denis
Director of Sports & Recreation,
The Mobility Project.

-----Original Message-----
From: Jon Pearlman [mailto:jlp46@pitt.edu]
Sent: Monday, March 08, 2004 12:52 PM
To: saintd@peakpeak.com
Subject: Sports Wheelchair

Dear Rich,
I was forwarded your email from Dr. Rory Cooper and Emily Zipfel about the sports wheelchair design. We have taken on your design as a small class project in a graduate level design class. About 10 of us are putting together a design for you. We are in the preliminary stages of the design and I will keep you posted as we progress. Dr. Cooper set the cost at $125 or less without wheels. Are there any other constraints I should know about with the design?

Thank you,
Jon Pearlman, M.Sc.

Photos not included above

SLA MODEL