Project Proposal and Feasibility Study

Team # 8

Papa Wheelie

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Abstract

Wheels for the World is an organization dedicated to providing mobility for disabled people in third world countries. Currently the business is receiving donated wheelchairs which are then outfitted with an "all-terrain adaptor" to make them more usable on rough terrain. While this can be done at a low cost, the wheelchairs are not able to withstand tough use imposed by rough terrain and dirty environments over time. A need exists for a new wheelchair specifically designed for rugged terrain. The new chair must provide quality and strength at a low cost and fit within several additional design parameters dictated by Wheels for the World.

1. Problem Statement:

Design and build a low cost, robust, all-terrain wheelchair for use in third world countries.

2. Project Objectives:

2.1 *Total cost should be less than one hundred dollars.*

Currently Wheels for the World is receiving donated wheelchairs from the United States and modifying them for all-terrain environments. To adapt to rough terrain, they are replacing the traditional front casters with a single larger wheel. The all-terrain adaptor is manufactured in United States prisons where labor costs nothing. As a result, the total cost for the current modified wheelchair is very low.

While Wheels for the World is successfully producing the modified version, there is a need for a more robust design which caters specifically to use on rough terrain. Since costs for the modified version currently in production are low, the new design must have tight cost constraints in order to make it favorable to the current version. Samuel Buxton, our contact at Wheels for the World, has given a maximum of one hundred dollars for the new wheelchair cost. The new design will also be manufactured in prisons, thus reducing labor costs to essentially nothing.

Early communication with Wheels for the World led us to believe that no design was currently in progress for an all-terrain wheelchair. Recently, we learned that another design has already been created to meet this need. The design was constructed by a consultant for the organization and will be tested in March 2005. Any design we create will also be submitted in the spring to the same contacts and the best design will be chosen. The estimated cost for the competitor's design is fifty dollars. Since this cost estimate is half of our budget, changes must be made in order to remain competitive. Either our target cost must drop to the same price range or our product must justify the added cost.

Initially the cost constraint of less than one hundred dollars seemed unreachable, but supplier research has made some low cost components available. In order to meet the fifty-dollar goal, intense research will be done to produce contacts for good quality low cost components. Ultimately suppliers will have a greater effect on total cost than design.

2.2 *Wheelchair must be manufacturable in prisons.*

Wheels for the World utilizes several prisons around the country for production of wheelchair components. The only component currently in production in prisons is the all-terrain adaptor for donated wheelchairs, but the new design will be almost entirely built by inmates. While manufacturing in prisons removes labor costs from total wheelchair cost, special consideration must be given to the assembly process and materials required for assembly of the complete wheelchair.

The facilities used for wheelchair assembly are equipped with metal working equipment, but not to the same extent as a factory specific to wheelchair production. As a result, the design must be simplified in order to decrease the complexity of construction. Factors such as the number of bends and number of welds for a tube will be reduced to a minimum. While the manufacturing process is not a main influence for design, it is important to consider and will affect many choices surrounding the final product.

2.3 *Design must be foldable/collapsible.*

A main design requirement for the all-terrain wheelchair is that it be foldable. While this requirement complicates design, it allows the wheelchair to be shipped easily and fit in car trunks or other small spaces for storage and transportation. Since the wheelchairs will be manufactured within the U.S., they must be transported to the many countries around the globe. As a result, shipping space is limited and the more compact the wheelchair can become the more chairs can be shipped to meet the need.

Some confusion may exist regarding the difference between a foldable and collapsible wheelchair. A foldable chair always remains completely intact, but is able to fold and compact into a smaller space. A collapsible chair does not remain connected and can be broken down into a number of smaller pieces.

It appears more feasible to make a collapsible wheelchair than a foldable version. In addition to being easier to design, a collapsible chair can be broken down into several pieces and stowed into smaller spaces. A foldable wheelchair requires less effort to compact, but will be more difficult to design. While there are advantages to each type, a collapsible wheelchair meets the design requirements given by Wheels for the World and will be easier to produce than a foldable version.

2.4 *Design must be robust.*

The goal is to produce a wheelchair tough enough to handle heavy use without needing major repairs. Most of the prospective wheelchair users have little experience with wheelchair use or maintenance. The conditions in the destination countries can also be rugged and dirty. As a result, an all-terrain wheelchair must be strong and able to withstand heavy use and even abuse.

One area of concern is the rear wheels and tires. While pneumatic mountain bike style tires provide good traction and a softer ride than solid tires, wheelchair users often continue to use their chair even if they have a flat tire. In this case, the rim becomes bent and the wheelchair's effectiveness is significantly reduced. If a wheel is bent, tracking straight will become nearly impossible, maneuverability is more difficult, and the wheel may rub against the frame requiring more power and inducing heavy wear on the tread.

In addition to wheels, durability is key when choosing a seat material. A good material must be soft yet strong, water proof, sturdy, and pliable. Fabric color is also an important consideration. A dark colored material will heat up in sunny climates, but a light color shows dirt easily. A number of considerations exist when choosing a seat material, the most important being material strength.

Robustness affects frame design heavily. Although the frame will be composed of strong steel or aluminum, joints and connections have the greatest potential for failure. Factors affecting frame material strength are wall thickness and number of bends in the steel. Important aspects to consider with connections are use of ball bearings, bushings, or other fittings. Some are tolerant to dirt and are durable while others may degrade quickly in a rugged environment.

2.5 *Design must be simple and composed of few parts.*

Simplicity is important to meeting the specified design requirements. Keeping the design simple has a number of benefits. Since the frame material will most likely be steel, fewer parts translates into greater weight reduction. Using less steel also lowers material cost allowing money to be allocated to other parts of the wheelchair or reducing total cost.

While weight and cost savings are the biggest benefits, a simple design may also reduce risk of failure. If fewer parts are used to construct the product, less points of potential failure exist and the remaining ones can be focused on and strengthened if necessary. A simple design is altogether easier to modify, easier to produce, and safer than a complex version.

2.6 *Utilize three wheel, extended fork design to move center of gravity back and make the wheelchair easily maneuverable.*

Wheels for the World strongly recommends the use of a three wheel extended fork design. While this is not a design requirement, years of testing and experience suggest that this design is optimal. By using three wheels instead of four, the center of gravity is shifted back directly above the rear wheels. This takes pressure off the front wheel and increases maneuverability.

While an extended fork (see section 3.2.2) requires more material, it increases stability and spreads the weight distribution over a larger area. An extended fork ultimately increases wheelbase and allows for a larger variety of seating positions. Some of the ergonomics associated with recumbent bicycles may be incorporated into the wheelchair design due to the increased wheelbase.

2.7 *Create a comfortable and adjustable seat.*

A good seat design is crucial to producing a successful wheelchair. While a robust frame and a simple design are important, the product will be a failure if the seat is uncomfortable. The seats on previously produced all-terrain wheelchair models were not adjustable and appeared too upright. Several goals and ideas exist to guide the seat design process.

One goal is to make the seat back angle adjustable. This allows users to change their seating position according to preference. Reasons for needing wheelchair assistance vary greatly. While some people are able to control their upper body without much thought or effort, some may not function well in an upright position. Thus an adjustable seat back may allow the user to sit in a more effective arrangement.

Some ideas inherent in recumbent bike design are applicable to wheelchair seating ergonomics. Allowing the user to sit in a slightly reclined position may increase comfort and improve mechanical advantage. These ideas are worth considering for wheelchair users and further research is being conducted to produce a good quality seat.

2.8 *Allow the front wheel to rotate 360 degrees*

The front wheel is important to maneuverability. The ideal design uses a twelve inch diameter smooth wheel that can rotate in a full circle. Twelve inches is significantly larger than the standard wheelchair front caster, but a larger wheel diameter has several advantages. A wheel of this size reduces the chance of becoming stuck and allows the wheelchair to roll over obstructions more easily. A smooth tread also requires less effort to turn than an all terrain tread. A design incorporating these features allows the user to change direction and navigate around obstacles easier than the traditional design.

3. *Feasibility:*

3.1 *Physical and Technical Feasibility*

Designing a wheelchair is physically and technically feasible. Because today's wheelchairs have many complex parts, we do not have the time and resources to design a complex wheelchair that would be sold in the United States. However, the third world all-terrain wheelchair must have a simplistic design in order to be cost effective. As a result, the time needed to design the wheelchair will be shorter than that of a regular wheelchair. Thus within these constraints the project appears feasible.

3.2 *Financial Feasibility (3 Cases For Comparison)*

Financial feasibility is the most uncertain aspect of the project. The one hundred dollar cost constraint is very tight and until a design is finalized, parts cannot be priced out allowing the completion of a cost estimate. Instead of progressing blindly and hoping the product cost is within the parameters, three similar cases for comparison exist which give a good idea of the financial feasibility for the project.

3.2.1 *Wheelchairs from China*

Wheels for the World can currently purchase standard wheelchairs from China for approximately fifty dollars. These wheelchairs are not all-terrain, but they provide a reference for a first cut price analysis. If it is possible to purchase fifty dollar wheelchairs from China, it seems feasible that a one hundred dollar all-terrain wheelchair can be produced if low cost suppliers are used. Many of these suppliers are also out of China and if used, it seems feasible to keep product cost below one hundred dollars.

3.2.2 *Oral Roberts University*

Four years ago, the engineering department at Oral Roberts University (ORU) was contracted by Wheels for the World to design and build an all-terrain pediatric chair. This pediatric chair was essentially a scaled down version of the all-terrain wheelchair Wheels for the World desires now. The pediatric chair was constructed with many similar ideas in mind.

First, the ORU designed chair uses the three wheel extended fork design. The front caster stems off from a "fork" consisting of a single tube extending from the rear axle, as displayed in Figure 3.2.2. The rear wheels are full size pneumatic tires, suitable for rough terrain. The front wheel in Figure 3.2.2 is slightly different from the one suggested for an ideal full size model, although this will not affect overall price significantly.

Figure 3.2.2- Pediatric Chair

Seat material used on the pediatric chair is similar to the seat material desired for the full size model. Thus cost estimates associated with the seat design and fabrication will be similar for both chairs. The amount of material used for the frame will be greater on the full size model both because its dimensions are larger and because the frame design is more complex. While the ORU chair was not foldable, the full size version is collapsible thus increasing frame complexity. Frame material costs can be scaled up to obtain an accurate price estimate.

Both the pediatric chair and the proposed full size version have the same purpose and basic design, but several differences exist between the two models. The seat on the ORU wheelchair is very upright and is not adjustable. Although this cuts cost, adjustability is a feature which will be incorporated into the new wheelchair design. A twelve inch wheel will also be used as the front caster instead of the small solid wheel Oral Roberts used.

Despite these differences, many similarities exist between the Oral Roberts University pediatric chair and the newly designed full size model. As a result, the university's project cost can be a good reference for the new wheelchair. Their total wheelchair cost was $86.44 and the complete breakdown can be seen in Appendix A. The prices listed in bold are numbers which can be reduced for the new design.

The projected cost of $24.00 for rear wheels and tires is higher than necessary for the model under construction. Contacts at Wheels for the World have indicated that a rear tire and wheel can be obtained for approximately $5.00 using suppliers from China. Thus the total rear wheel and tire assembly would cost $10.00 yielding a $14.00 savings from the Oral Roberts budget.

The powder coat cost listed on the Oral Roberts price breakdown is $5.00. Although powder coating is nice, it is not necessary for basic wheelchairs being shipped to third world countries. Coating the steel frame with rust inhibitor or Rust-oleum can save cost and prevent oxidation of the frame. While not as permanent as powder coating, these methods provide protection for a lower cost. Powder coating costs have been included in a cost estimate for the newly designed wheelchair, but can be reduced to cut costs.

Finally, the labor cost listed is not necessary for the current budget. The new wheelchairs will be produced in prisons across the country reducing labor charges to essentially zero. After making these changes to account for the current situation, the revised budget proposal for the pediatric wheelchair is approximately $60. That is, the ORU pediatric chair could be produced for $60 dollars under the current conditions that exist. It then seems feasible that a full size model with some additional features can be completed for an additional $40 or less. Under these circumstances the new project budget is not exceeded.

3.2.3*The Design Competitor*

Since the project's introduction, a design "competitor" has emerged. Phil Yocum, a consultant for Wheels for the World, has been working on a design to meet the need for a full size all-terrain wheelchair. The initial perception was that a design such as this was not currently under construction. Mr. Yocum has been involved with Wheels for the

World for six years and has made several trips to Ghana with them. He is experienced in wheelchair prototype testing and his new design is complete.

Since this discovery, a phone call with Samuel Buxton indicated that both Mr. Yocum's design as well our design will be submitted to Wheels for the World and the best design will be chosen. The preliminary budget for the completed design is fifty dollars. Since this design was completed by a consultant with years of experience, his project budget proposal should be fairly accurate. This essentially proves the feasibility of an all-terrain wheelchair which is foldable and costs less than one hundred dollars.

3.2.4 *Lowering Cost Through Supplier Research*

While the final wheelchair design determines total price, costs can be lowered by finding the cheapest suppliers. Often these suppliers exist in Asia and may be difficult to locate. This being true, talking to the right resources can open doors for supplier contacts allowing low cost parts to become attainable. As a result, supplier research and contacts may affect final product cost as much as the wheelchair design itself.

3.3 *Overall Project Feasibility*

Given the financial information surrounding similar scenarios, it appears that the project is financially feasible. It is also clear that the production of an all-terrain wheelchair is physically and technically feasible. The project is progressing well and no doubts as to the feasibility of a complete product design and prototype exist.

4 Method of Approach

Embarking on a large project in an unfamiliar field is intimidating. In order to effectively begin, each team member did some preliminary research to become familiar with wheelchair use and design. The team split up and different members researched ergonomics, wheels, frame designs, and all-terrain features.

In order to supplement individual research, the team sought to establish a list of contacts who could give insight into wheelchair design. Meetings with a custom wheelchair seat specialist and a wheelchair distributor were good starting places for insights into frame and seat design. Through them we established additional contacts who will review the complete wheelchair design in January.

After an extended period of research, each group member was assigned to create an initial frame design. The entire team then reviewed the complete frame designs and the best designs were chosen to pursue. At this point, it became necessary to split up team members to pursue separate tasks. Prior to frame design, the team worked together on large tasks, but this proved to be inefficient. To increase team productivity, two members were assigned to frame design using Autodesk Inventor. One member was then assigned to webpage design and the other to Microsoft Project scheduling and any documentation.

The method of approach encompassed focusing as a team on research, doing some individual design work, and then splitting and completing separate tasks in pairs or individually. This method led to a slow start, but the design is progressing quickly because of an early emphasis on research. While operating individually on separate tasks, continuous communication is necessary and is being maintained through bi-weekly team meetings.

5. Task Breakdown and Scheduling

While the Microsoft Project schedule breaks the yearlong project into nearly one hundred tasks (see Appendix B), a few major milestones exist for the first semester. Major goals prior to Christmas break are the completion of an initial wheelchair design, the creation of a team webpage and the composition of a preliminary project and feasibility study. Although this may seem like a conservative number of goals, the design completion by Christmas is a demanding deadline. The complete wheelchair design encompasses frame, seat, brake, wheel, armrest and footrest components.

Although the technical project deadline is in May, we hope to take a completed prototype to Ghana in late March to test it and gain exposure to the countries where the wheelchairs will be sent. Thus, the project must be completed a month and a half before the deadline required for class. In order to meet this deadline, interim will be an intensive month of finalizing design, testing its components using finite element analysis, and preliminary prototyping.

6. Detailed Task Specifications

Timely completion of a number of tasks will be necessary for this project to proceed as scheduled. These tasks can be broken into three distinct categories: functional requirements, performance requirements, and construction requirements. Each of these major areas must be addressed in the design and manufacture of a successful wheelchair. A more detailed outline of task specifications is shown in Appendix C.

6.1 *Functional requirements*

Since wheelchairs have existed for many years, users have certain expectations associated with their function. The most basic component of functionality is providing comfort and mobility. These aspects must then be encompassed in a long-lasting robust design. This is of particular concern for third world countries where wheelchairs will be subject to harsher environments and heavier wear.

These practical functional requirements will be met in several ways. First, the wheelchair design will focus on ergonomic ideas which provide the user with the greatest comfort within the chair. These factors will play a large role in defining frame dimensions, such as wheel placement and seat height. Also, the dimensions of the frame will be chosen to provide the greatest mobility while maintaining safety. To ensure a robust design the frame will be made of tubular steel that will ensure rigidity. Special attention will be shown to connections between the parts because these areas are most likely to fail.

6.2 *Performance requirements*

A significant factor of any design is its performance under real world operating conditions. For this project to succeed, the wheelchair must operate in the harsh conditions found in third world countries. These regions are known for terrain that is uneven, rocky, and rugged. Because many wheelchairs are not built with off-road conditions in mind, they cannot tolerate harsh conditions over time. These chairs are built to be used by people within the United States where roads and sidewalks are level and well maintained. The design specified in this report will deviate from the traditional wheelchair design to accomplish greater off-road performance and durability.

The major difference between the proposed design and standard wheelchair is the new design will utilize three wheels instead of relying on four. The front wheel will be larger than the traditional one and extends out in front of the frame. This characteristic will improve the performance of the wheelchair in off-road situations in two ways. First, the larger front wheel will make it easier for the chair to circumvent obstacles in its path. Second, by extending the front wheel away from the frame a large percentage of the wheelchair's load will be supported by the large rear wheels due to their close proximity to the center of mass. In other words, a front wheel that is moved away from the frame will be less likely to become stuck in loose soil because it is not supporting as much of the weight. Another way in which the design performance will be improved over existing wheelchairs is by cambering (angling) the rear wheels to increase the stability of the chair in the rugged terrain.

***6.3** Construction requirements*

The third major task that must be addressed is the mass production of the final wheelchair design. This concern must be addressed in two ways. First, the wheelchair must be designed in a way that allows it to be produced within United States prisons. This means that the design aspects must take into account the machining capabilities of the prison. Second, the wheelchair design must be as easy to assemble as possible. This can be done by having a small number of simple parts. The resulting design will have less assembly requirements and fewer joints where failures are possible.

7. Christian perspective

The scope of our project provides support for the fact that Christian engineers can serve God in their work. The Christian Reformed doctrine calls for us to be a part of the world taking ownership of its many hardships. The design of this wheelchair gives new hope to thousands of people that are in need of mobility. The design norms below discuss the impact of such a design on the environment in which it will be used.

***7.1** Caring and Justice*

The core of this project is about caring for people lacking independence. Wheelchair supply in third world countries often cannot meet demand. In these areas there are many people with disabilities lacking mobility that are dependent on others for their daily needs. When given a wheelchair, they receive the freedom to move on their own. The privilege of mobility is a seemingly necessary component of human life.

People who have been given a new sense of mobility often experience a new found wellness and self-esteem.

7.2 *Cultural Appropriateness*

Several different cultural considerations are associated with the project. Most importantly, the recipient of the wheelchair and their culture must be addressed. While the modified wheelchairs currently being sent out meet a need for better mobility, they are not durable enough to be a lasting solution. A new design will be constructed using materials indigenous to third world countries. It will be a more permanent solution designed specifically for the terrain in these areas. The wheelchair will also be adjustable in order to accommodate a wide variety of body types and disabilities.

Another culture to consider is the one within the manufacturing facility. Since prisons will be used to produce the new design instead of factories, resources and skills will be limited. In order to make assembly easier, fewer parts and an emphasis on simplicity will best serve the workers. An assembly manual and jigs to aid manufacturing can be created to help the prisoners effectively do their job. Such cultural aspects are being considered in our preliminary designs.

7.3 *Integrity*

The ultimate goal of this project uses the gift of a wheelchair as an opportunity to expand the kingdom of God. The act of kindness and generosity that one shows when providing a wheelchair to someone in need opens doors with people and provides a common link for further growth. Wheels for the World incorporates the Gospel with the distribution of their wheelchairs. In partnering with such a ministry, we can use our engineering skills to meet a real worldwide need as well as open doors through which the Word to spread.

8. Cost Justification

The costs associated with this project have been estimated at $144 for the prototype wheelchair. An outline of the expected costs can be seen in Appendix D. The cost exceeds the budget requirement of $100 given to us by Wheels for the World. However, the prices quoted within the estimate do not reflect bulk discounts that Wheels for the World receives. For instance, our estimated price for wheels is $20 each based on current catalog information. However, Wheels for the World has can obtain both rear wheels and tires for ten dollars. Additionally, all the items listed within this estimate might not be used within the final design. An example of this is power coat cost. If cost cuts are necessary, powder coating can be replaced with a cheaper alternative.

The project budget is within the three hundred dollar limit dictated by the engineering department for the course. The prototype budget also assumes no parts will be donated. Two major cost reducing goals are to obtain free wheels and frame material. While this appears feasible, no assumptions were made in case donations could not be found.

9. Alternative Designs

As previously mentioned, the cost requirement is a major factor influencing design. Thus we are faced with an optimization problem involving robustness and cost. In our situation, we've been given a maximum cost requirement of one hundred dollars. With such a small budget, many sacrifices need to be made which affect the durability and capability of the wheelchair. The wheelchair has to be able to provide security on rough terrain while surviving harsh conditions and heavy use. These trade-offs have played a large role in our design process. We approach the solution to these trade-offs with optimism and ingenuity.

The design process began with brainstorming many different components inherent to wheelchair design, as outlined in Appendix E. The brainstorming was done by the entire group. From there, the ideas were narrowed down by selection of what the group thought was the most desirable option. Different component designs were selected, two final design alternatives were created, and we chose the best design to pursue.

9.1 Frame

The frame is the most important part of the design to consider. It incurs much of the project costs, determines the rigidity of the chair, and connects all other components into one functional design. Our current ambition is to maximize rigidity by minimizing the number of members and joints possible. This strategy works conjunctively for minimizing weight and costs as well as difficulty of assembly and transport.

It is essential that a light and durable material be chosen while staying focused on the cost constraints. Current thought is to make the frame and many other wheelchair components out of steel, which is strong and cost effective yet very machinable. Steel is a commonly found material that is often less expensive in third world countries than in America. The down side of steel is its heaviness, but wheelchair weight can be minimized by using smaller tubing because steel is strong.

The frame has to be durable because all the other parts of the wheelchair attach to it. The project specifications include durability as well as foldablity. Unfortunately, a rigidity tradeoff exists when making a foldable frame because of the joints. This has to be taken into consideration as an optimization between foldability and rigidity was reached. All frames considered also incorporated a three wheel design with the front wheel extended out in front of the wheelchair. This helps to transfer weight from the front tire onto the back tire and provides additional maneuverability.

9.1.1 *Proposed Design #1- Single Extended Fork Design*

This design (Figure 9.1.1) focused on providing a very rigid frame. The frame was a simple T bar welded together. The seat was welded directly to the frame in this design. The design of this wheelchair had the look of a typical basic wheelchair with an upright seat attached to the base. Because every part of this frame is welded together, it is very rigid. However, it is not foldable and assembly is difficult. Because this design was not foldable, it was not practical as a final design option.

Figure 9.1.1 Single Extended Fork Design

9.1.2 *Proposed Design #2- Standard Compactable Design*

This design (Figure 9.1.2) had a frame with an upright seat typical of most basic wheelchairs found on the market in the United States today. This design focused on making the wheelchair “foldable.” Instead of having a frame that folded down into one compact assembly, this frame could break down into separate pieces. These pieces could then be stored together in a small area like a wheelchair that folded into a compact shape.

This design was constructed by having two primary side pieces that made up the seat and part of the frame. These pieces

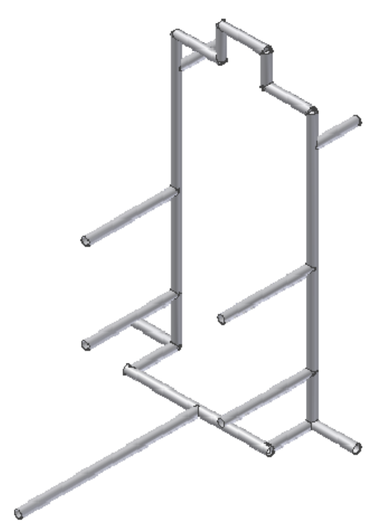


Figure 9.1.2 Standard Compactable Design

were held together by a T bar on the bottom that acted as a base and a bar running across the top of the frame. If these two pieces were removed the frame could be collapsed into a compact shape. The drawback of this frame design is its lack of rigidity. There is a chance of frame failure at the joints where the frame slides together.

9.1.3 *Recumbent Collapsible Design*

This frame has a design similar to that of a recumbent bike. The frame is composed of two tubes connected together by curved forks. The forks are held together by a pin that goes through their center. This pin is connected to an assembly that contains the front caster. The assembly can swing freely and rotate 360 degrees. The seat is attached to the frame in a recumbent position. Supporting cross members prevent the frame assembly from swinging together. This design provides a more rigid frame than a completely collapsible model and still can be broken down for storage. However, there is some concern that the front caster assembly would not effectively rotate 360 degrees due to the friction created by the tire as it swings across the ground.

9.2 Wheels

Wheels are an important component where several different possibilities exist. Wheel selection is crucial because traction is key to off-road capability. While it is certain that an all-terrain tire will be used, a number of design considerations must still be specified. As a result, many options for the tires and wheel assembly were considered.

9.2.1 *Pneumatic*

The first option investigated was pneumatic tires for our wheelchair. Pneumatic tires are cheap and are readily available in the United States. Using pneumatic tires also provides some natural shock absorption without investing money into a shock system. Because of their cost and availability, pneumatic tires seemed like the best choice. However, these tires are susceptible to puncture and frequent repair may be necessary. Pneumatic tires are easily replaced in the United States, but availability varies in the third world countries. The rough terrain also lowers the lifetime of the tires. This further exacerbates the problem of tire replacement in a third world country.

9.2.2 *Non-Pneumatic*

Another option considered for tires was non-pneumatic tires. This would help solve the problem of tire puncture and replacement due to the rough terrain and solid wheels could last the lifetime of the wheelchair. One problem with this option is that non-pneumatic tires are harder to find and more expensive. Non-pneumatic tires also do not absorb shock as well as pneumatic tires do. However, if solid all-terrain tires can be purchased within our budget they are favorable to pneumatic tires.

9.2.3 *Straight vs. Cambered*

Wheels can be mounted to the frame either straight up and down or angled (cambered). The easiest option is to mount the wheels straight, as with the common wheelchair. This option provides the easiest way to grip the wheel and provides the least resistance when the chair is pushed. Unfortunately, the straight mounted wheelchair may be unstable with this setup if it goes over very rough ground.

In order to improve stability, cambering may be implemented. By angling the wheels between five and ten degrees, the wheelchair provides much more stability over rough terrain. One drawback of cambering the wheels is that more of the wheel contacts the ground. This produces more friction and makes the wheelchair harder to push. While this is a concern, the added stability benefits the design much more than the friction hampers the design.

9.2.4 *Handrim*

Cost is an important project parameter which necessitates a simple design. In an effort to reduce material cost, a standard mountain bike tire without a hand rim can be implemented. This design alternative requires that we provide a pair of gloves for the wheelchair recipient to wear because they would turn the wheels directly, instead of with a hand rim. While this seems to deprive the customer of an essential wheelchair feature, most of them have never had access to a wheelchair before. They will be less likely to care if they get dirty hands turning the wheel and will be satisfied with any good all-terrain model. Under the circumstances, the mountain bike tire and glove option will only be implemented if cost reduction is necessary. A hand rim is a luxury we would like to provide.

9.2.5 Current Plan

Since common prices for prefabricated wheelchair wheels range from $75 and up, the current plans for the wheels are to obtain used or rejected (non-structurally flawed) 25-30 inch diameter mountain bike tires and wheels. These wheels will be mounted onto the frame in a cambered fashion to increase stability. The third caster wheel is estimated to be between 12 and 18 inches in diameter for the purpose of tackling larger obstacles in an all-terrain environment. This design provides light weigh good traction at an affordable price. In addition, although inner tubes are required, bike tires are a fairly common commodity in some third world countries, allowing for easy replacement and a cushion in ones ride.

In consideration of the mountain bike application there are essentially two different types of options that concern our design: Spokes vs. Mag. Spokes are lighter, cheaper and offer a softer ride. For Mag wheel considerations, refer to the Figure 9.2.5.

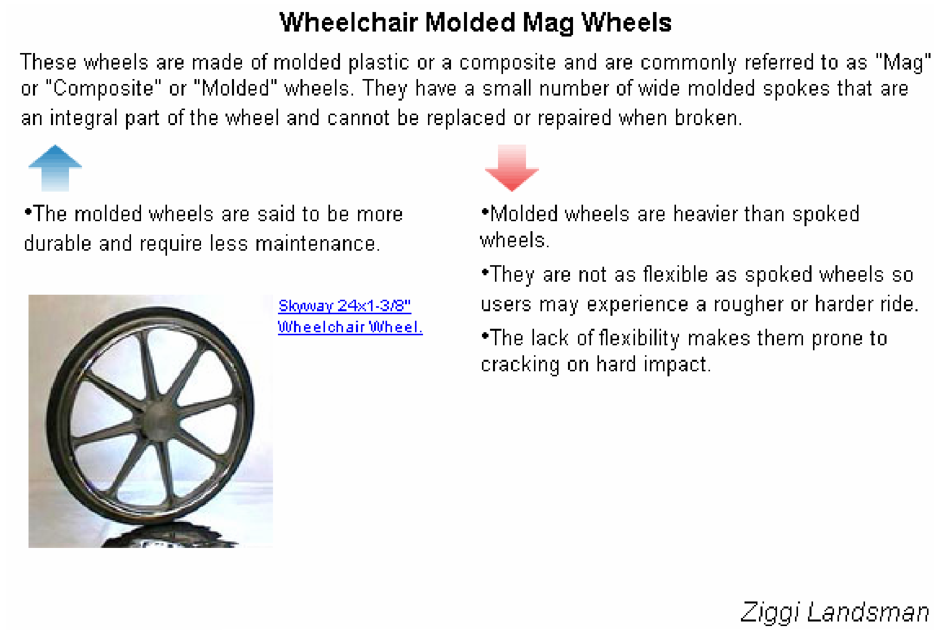


Figure 9.2.5- Mag Wheels vs. Spoked Wheels

Many of these considerations will depend on the cheapest supplier we can find. Right now, research shows that wheels can be obtained from China for five dollars each. This will most likely be the only way to keep within budget.

9.3 Seat

The seat is the most important component attached to the frame assembly. A seat is used to cradle the person in the wheelchair. Since the people who use wheelchairs are generally frail, it is essential that we provide as much comfort and support as possible within the limits of the project. Regardless of how good the seat design is, ultimately each wheelchair should be custom tailored to the individual. While this is ideal, it is not necessary for the third world or within the scope of our project. As a result, the wheelchair seat needs to be as generic as possible in order accommodate many people and to make slight modification of the chair to a person's particular needs possible.

9.3.1 *Tilted Seat*

The initial design considered was a standard seat with a tilted back. A ninety degree seat angle was ruled out almost immediately because it provides little support and is uncomfortable. The tilted back allows gravity to help hold the person in the wheelchair as well as provide some comfort while sitting in the chair (see Figure 9.3.1). Because the wheels will be mounted slightly behind the seat, this design also provides easier access to turn the wheels. One drawback of this design is that there is no way to adjust the seat from its initial position. The tilted back is better than the straight back, but the position could still become uncomfortable after sitting in the chair for awhile.

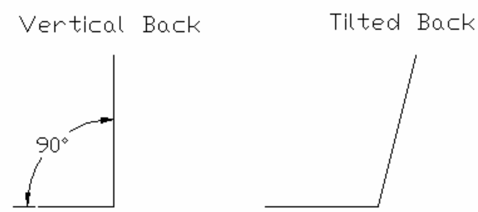


Figure 9.3.1- Seat Back Angles

9.3.2 *Fully Recumbent*

This design meshes a unique seat and frame combination which incorporates the ergonomics behind recumbent bike design, as shown in Figure 9.3.2. In a recumbent style wheelchair, the seat back would be tilted and the user's feet would extend further forward than on a traditional wheelchair.

Figure 9.3.2- Recumbent Bike

This design provides more comfort for the individual than a tilted seat with a standard setup. It also prevents the person from slowly slouching down in the seat. On a recumbent design, the user would sit slightly lower to the ground. This design does provide comfort, but may make it difficult for the person to have enough leverage to turn the wheel effectively.

9.3.3 *Swappable Seats*

The previous seat design considerations did not include means for adjustment. A way to fix this is to provide a common base frame to which a number of different seats could be attached. This partially solves the problem of adjustability by providing a number of different seat positions for the same wheelchair frame. The different seats with varying positions could be swapped to cater individual's needs.

This is a great option to provide a person with the most comfortable seating position. However, in order to have a wheelchair with multiple seating positions, a person would need to have more than one seat. Because of this, it is more favorable that someone would choose their favorite position to be sitting in rather than having multiple seating positions. While this idea improves adjustability, it is not cost effective.

9.3.4 *Two Frame Fully Adjustable Seat*

The only way to have many different seating positions without using excessive amounts of material is to design a seat that is fully adjustable. In order to accomplish this, certain joints will be held together with pins instead of being welded. This creates a linkage system that can be used to adjust the position of the seat. This design was desirable because it provides the option of sitting tilted, recumbent, or anywhere in between. It uses much less material than having swappable seats and also provides more adjustment options. This does make the chair less rigid, but using strong pins with tight clearances should be adequate to hold the joints together.

Currently, thoughts are to construct the seat frame separately from the base frame. This allows for compactability and ease of assembly. Ergonomically, thoughts are to give the seat a more reclined position, such that the chair slightly cradles the person similar to the posture of an ergonomic body chair. This should accomplish two things. One, in this reclined position weight will be shifted from the seat to the back, thus decreasing the chance of pressure sores and discomfort. Second, the reclined position holds the user secure on rough ground. This proves to be an important factor in many circumstances when the user has lost full capability of his/her legs.

In common designs, the problem of people sliding out of the seat is countered by adding ridges to the front of the seat. However with our limited budget the reclined position accounts for this problem in a more functional manner and allows us to use a cost effective weather resistant cloth. The cloth will be sewn over two parallel L-shaped bars that will make up the frame of the seat. The seat will be locked rigidly by a similar pin-in-slot mechanism, as found in the main frame design, and slid on a smaller pipe connected from the top of the frame. In addition, future hope incorporates placing an adjustable back support into the design.

9.4 Seating Material

After considering frame design, the material of the seat needs to be considered. Seat material can be broken down into two parts: padding and covering. The padding needs to provide cushion while also helping the user to maintain good posture while seated. Often wheelchair users find it difficult to maintain good and comfortable posture in a wheelchair for long periods of time. Major reasons for this are lack of leg strength to adjust position and reduced feeling to know when movement is necessary.

For an all-terrain wheelchair, using the proper covering is important as well. The covering of the seat must survive a harsh environment and remain intact. Material lifetime is a big factor in deciding what type of material to use in the seat. The materials used for the seat may not be readily available in some third world countries. Because of this, the less the material needs replacement the better. Ease of assembly is another consideration in the design of the seat. The easier the material is to integrate into the seat and frame design the better it will be.

9.4.1 *Foam Pad*

A foam pad was one of the first ideas of seating material to use. Foam padding would be the most comfortable material to cover the seat with. It would also provide the most support for the person using the wheelchair. However, foam is hard to integrate into the seat design because a plate must be fabricated to mount the foam to. A plate like this would then be mounted to both the seat bottom and seat back. Problems with this approach are that the plate hinders collapsibility of the whole frame and soft foam wears out easily. Foam seat replacements are not readily available in all third world countries. In addition, collapsibility is a project requirement and cannot be compromised.

9.4.2 *Sleeve*

Another option is to sew a piece of fabric so that it can slide over the tubes of the seat bottom and back. This option does not provide as much comfort and support as foam, but it does integrate with the seat much better (see Figure 9.4.2). The sleeve would slip over the frame without the need of an additional mounting plate. This design would probably wear out faster but it would be much more likely that a new sleeve could be fabricated in a third world country. If necessary, shipping these sleeves to the third world country is feasible at a low cost. An additional benefit of the sleeve is that would not need to be removed for the wheelchair to fold up. The material will be flexible and soft, so it would compress along with the frame.

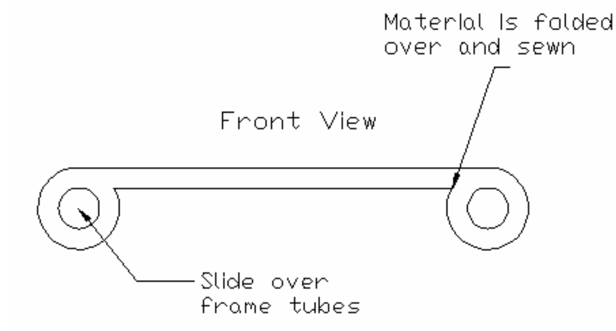


Figure 9.4.2- Sleeve Fabrication

9.5 Foot Plate

The footplate provides a rest for the user's feet as well as supports to prevent them from sliding out of the chair. This is a fairly simple component. The only big decision involved with the footplate is to decide how to integrate it into the frame.

9.5.1 *Integrate onto Frame as a Separate Piece vs. Weld to Frame*

One way to integrate the footplate onto the frame is to fabricate the footplate as a piece that could snap or bolt onto the frame. The advantage of this design is that the footplate could easily be removed for wheelchair storage. This method of attachment would also help to strengthen the front of the wheelchair frame. Another way of attaching the footplate is to weld it to the frame. This method provides a stronger connection between the footplate and the frame, but also could hinder compact storage. This type of connection would also require the footplate to be made in two separate pieces so that the frame could still be broken down. It would be more desirable to have one piece as the footplate.

10 Final Selections

After all parts of the wheelchair have been considered, two final design alternatives were proposed. These designs incorporated the best aspects of the specific components of the wheelchair system. With these two final design alternatives, a final design will be constructed.

10.1 *Final Alternative 1*

The first design alternative utilizes the robust two bar frame, as shown in Figure 10.1. The frame itself mimics a blend of a wheelchair and recumbent bike. With a design conducive to three wheels, it incorporates a more elongated frame made up of two main bars connected by a vertical peg in the front caster. These two bars are then made rigid by a bar that fastens the two bars together towards the back of the frame by a pin-in-slot design mechanism.

Figure 10.1- Final Alternative 1

However, instead of putting the pin through two curved forks at the front of the frame the pin is placed through "donuts." These donuts are used because they are easier to fabricate and provide more strength. The front caster assembly on this design was also changed. The caster assembly used has no radius going from the fork and wheel to the pin. This allows the caster to turn on a point instead of having a radius. This reduces friction and makes the caster assembly work better. The wheels on this design are cambered for increased support despite increasing friction. Non-pneumatic tires were chosen as the wheel for this design.

The seat is made to be adjustable. It is composed of two primary bars that lock into the frame with pins. The attachment points are located on pegs that are welded to the frame. The pins provide the freedom of adjustment for the seat. The seat is covered with a fabric sleeve to be used as the seat and back rest. Four cross bars were put across the frame and seat in order to stabilize it. These bars are held in place with a slotted locking system. Finally, the footplate in this design is welded to the two frame bars.

***10.2** Final Alternative 2*

This alternative was the same as alternative 1 except for a few key features. In this design the frame bars were bent up in the z direction to accommodate the front caster better. Doing this also provides a place to mount the footplate without welding it to the frame. Because of this, the footplate was made in one piece.

Appendix A

COST ESTIMATE

- Materials sourced in Kenya. Currency converted to U.S. Dollars.
- Prices for components of single chair.

Frame and Parts:

Seat Material	$1.00
Wheel Assemblies (Rear Wheel Assembly and Tire)	**$24.00**
Front Wheel	$3.00
Nylon Bushings	$4.00
1 in. Steel Tubing, 25ft.	$4.00
Fasteners, Miscellaneous	$2.00
Axle (½ in. round stock)	$0.50
Armrest padding and other Miscellaneous costs:	$5.00

Wheel-locking mechanism:

2- Pull to Lock Lever Systems	$14.00
2- Mounting Brackets	$5.00
4- ¼ - 28 Serrated Flag Nut (With Patch)	$1.50
2 - ¼ - 28 Automation Nut	$1.00

Footrests:

¼ in. Flat Stock	$1.00
Flat Bar	$0.50

Manufacturing:

Welding, 1 Bottle	$1.26
Welding, ½ lb. Rods	$3.68
Powder Coating Finish[1]	**$5.00**
Labor	**$10.00**

Total Cost Estimate

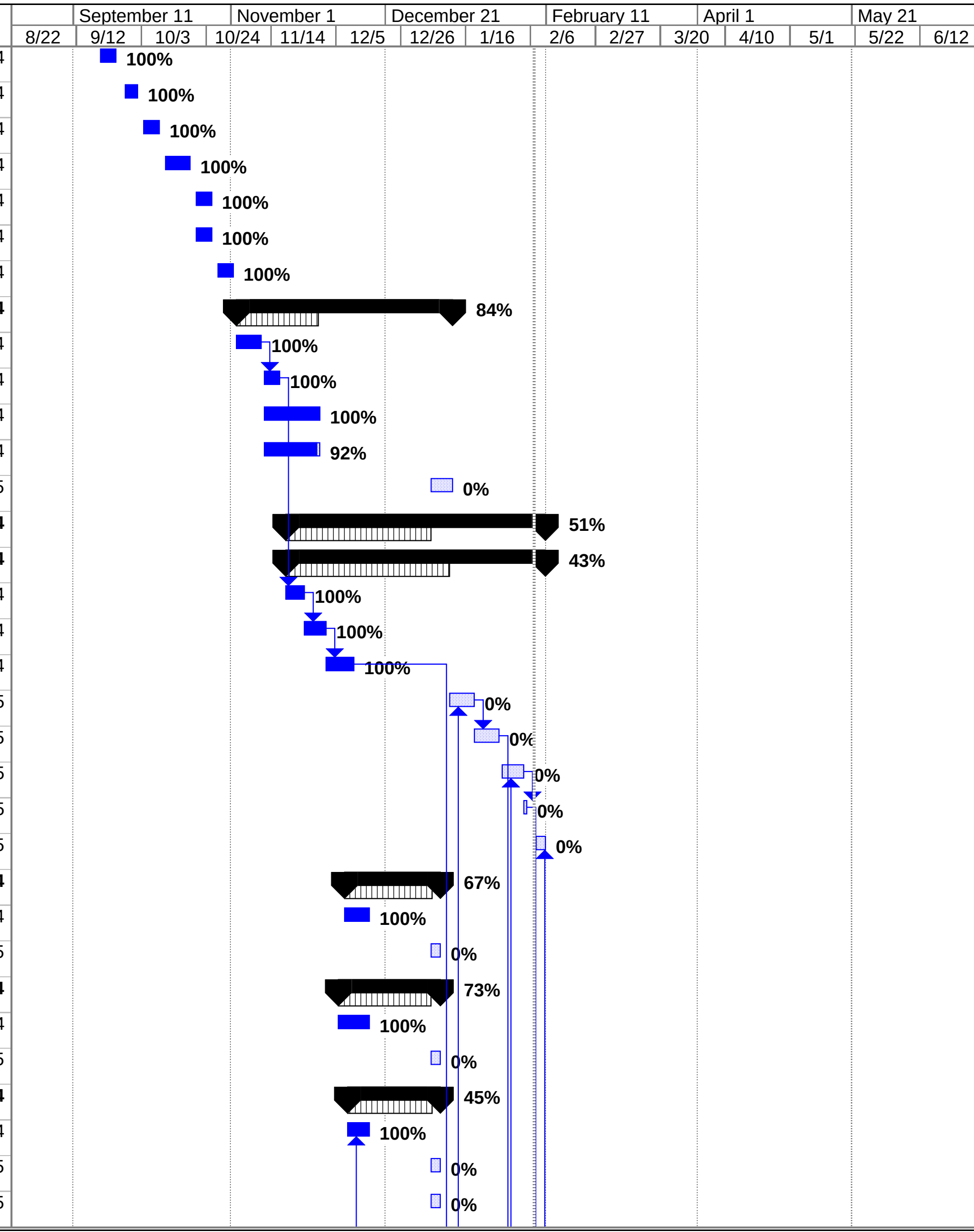
Total	$86.44

1 The powder coating equipment will have to be purchased. That upfront cost is not included in the powder coating cost estimate, which only reflects the cost of powder per chair.

Appendix B

Microsoft Project Schedule

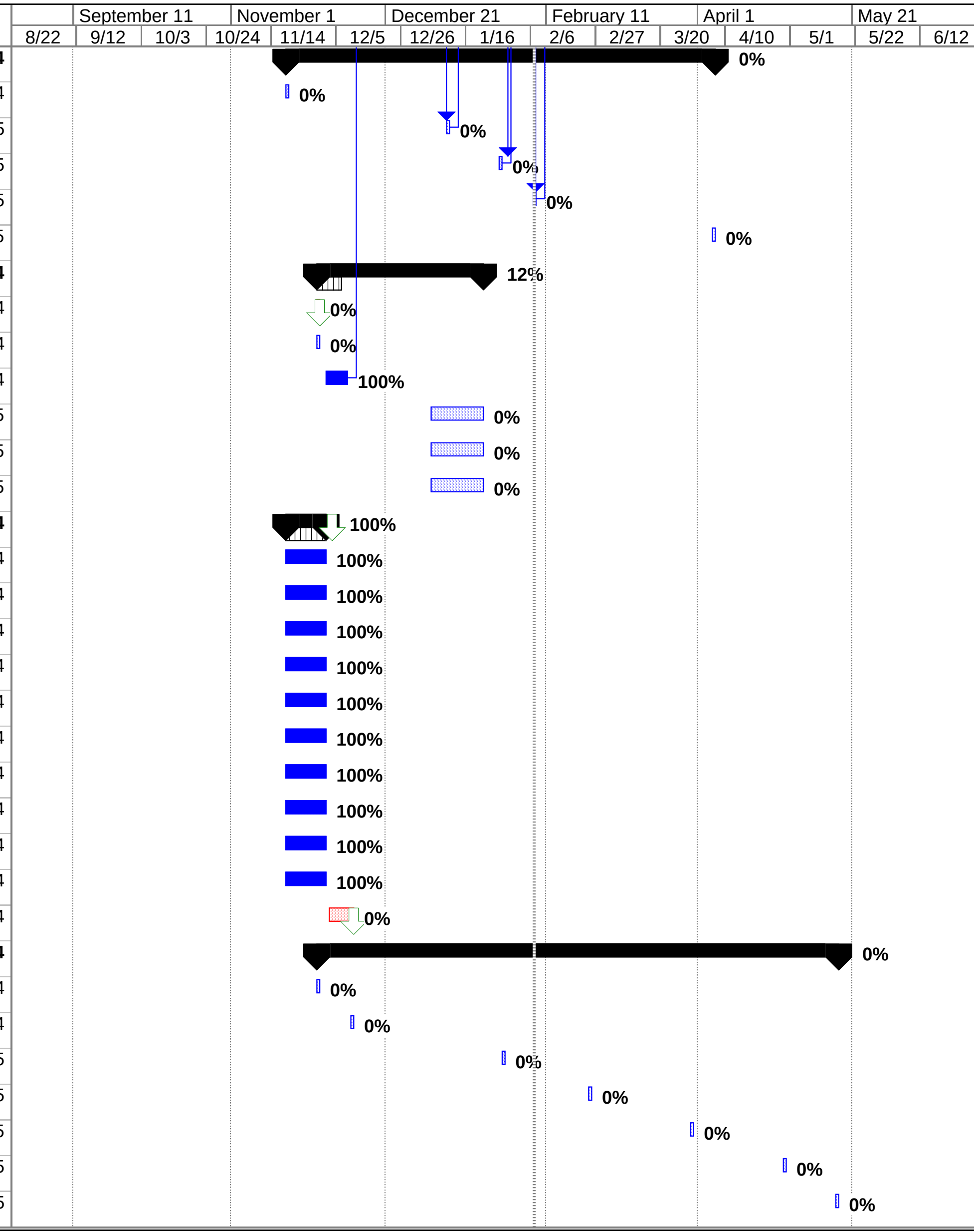
ID	Task Name	Duration	Start
1	Project Definition	5 days	Mon 9/20/04
2	Project Objectives Defined	4 days	Tue 9/28/04
3	Alternative Solutions Proposal	5 days	Mon 10/4/04
4	Preliminary Task Specifications	6 days	Mon 10/11/04
5	Preliminary Feasibility Eval	3 days	Thu 10/21/04
6	Preliminary Budget Eval	3 days	Thu 10/21/04
7	Refined Task Specs	3 days	Thu 10/28/04
8	**Brainstorming**	**51 days**	**Wed 11/3/04**
9	Brainstroming Frame Design	6 days	Wed 11/3/04
10	Initial Frame Design Sketches	3 days	Fri 11/12/04
11	Seat Design Brainstorming	12 days	Fri 11/12/04
12	Wheel Integration Brainstorming	12 days	Fri 11/12/04
13	Brake Design Brainstorming	5 days	Wed 1/5/05
14	**Wheelchair Design**	**63 days**	**Fri 11/19/04**
15	**Frame Design**	**63 days**	**Fri 11/19/04**
16	Preliminary Design Choice	4 days	Fri 11/19/04
17	Preliminary Design Into Inventor	5 days	Thu 11/25/04
18	Finalize Preliminary Design for Review	8 days	Thu 12/2/04
19	Re-work Preliminary Design	7 days	Tue 1/11/05
20	Secondary Design for Review	7 days	Wed 1/19/05
21	Re-work Secondary Design	5 days	Fri 1/28/05
22	Final Design for Review	1 day	Fri 2/4/05
23	Re-work Final Design	3 days	Tue 2/8/05
24	**Wheel Design**	**23 days**	**Wed 12/8/04**
25	Draw Wheel Design in Inventor	6 days	Wed 12/8/04
26	Incorporate Wheel/ Axle into Design	3 days	Wed 1/5/05
27	**Seat Design**	**25 days**	**Mon 12/6/04**
28	Add seat into Inventor	8 days	Mon 12/6/04
29	Incorporate Seat into Design	3 days	Wed 1/5/05
30	**Brake Design**	**22 days**	**Thu 12/9/04**
31	Draw Brakes in Inventor	5 days	Thu 12/9/04
32	Add Brakes onto Wheelchair	3 days	Wed 1/5/05
33	Research tube pending procedure	3 days	Wed 1/5/05



Project: Project Schedule.mpp
Date: Mon 2/7/05

Critical | Split | Baseline Milestone | Project Summary
Critical Split | Task Progress | Milestone | External Tasks
Critical Progress | Baseline | Summary Progress | External Milestone
Task | Baseline Split | Summary | Deadline

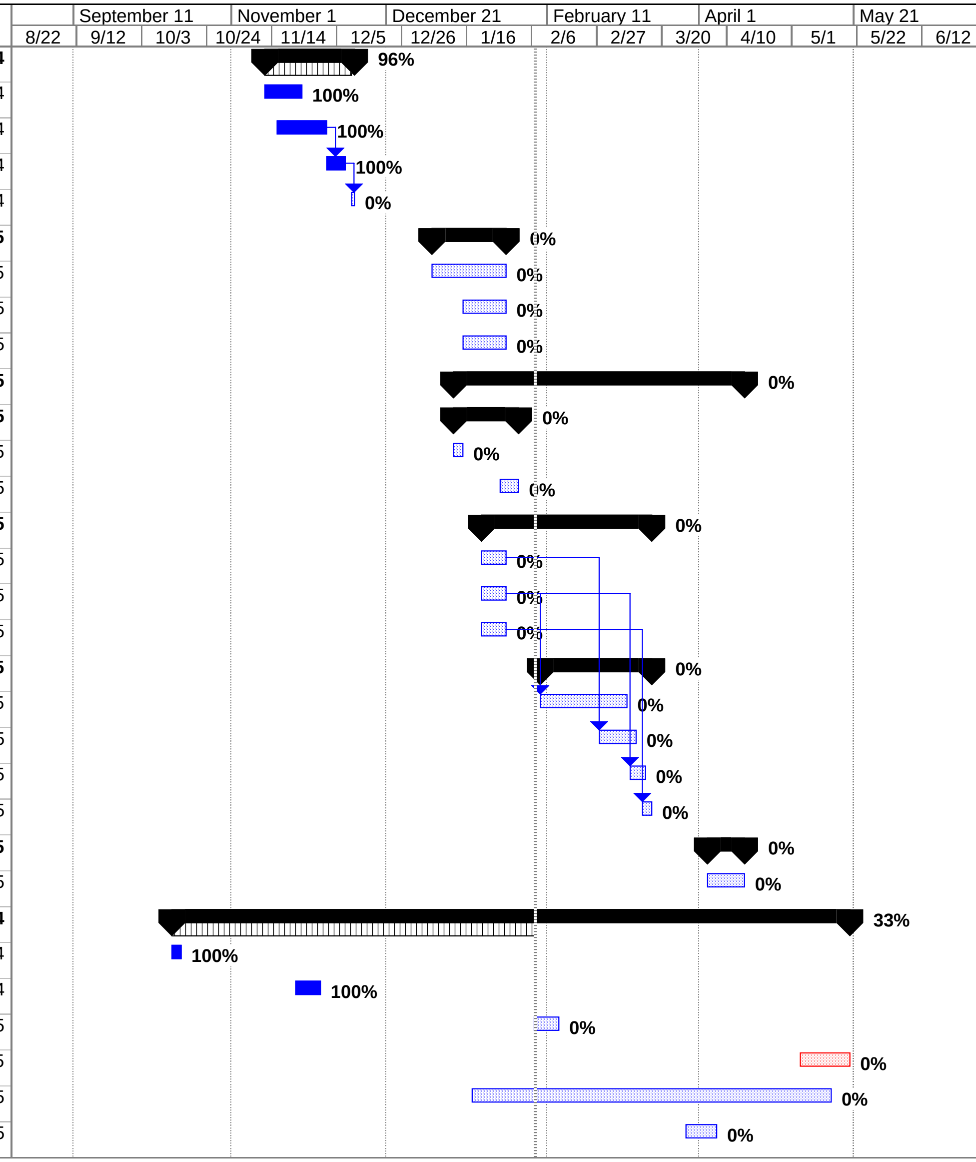
ID		Task Name	Duration	Start
34		**Design Reviews**	**102 days**	**Fri 11/19/04**
35		Fall Design Review With Mr. Spoelhof	1 day	Fri 11/19/04
36		Prelim. Design Review With Wheelchair Experts	1 day	Mon 1/10/05
37		Secondary Design Review w/ Expert	1 day	Thu 1/27/05
38		Final Design Review w/ Experts	1 day	Mon 2/7/05
39		Spring Design Review With Mr Spoelhof	1 day	Wed 4/6/05
40		**Research**	**42 days**	**Mon 11/29/04**
41		Seat/Ergonomics Research	1 day	Mon 11/29/04
42		Wheel Research	1 day	Mon 11/29/04
43		Brake Designs	6 days	Thu 12/2/04
44		Supplier Research	14 days	Wed 1/5/05
45		Material Research	14 days	Wed 1/5/05
46		Material Availability Research	14 days	Wed 1/5/05
47		**PPFS rough draft**	**9 days**	**Fri 11/19/04**
48		Problem Statement	9 days	Fri 11/19/04
49		Project objectives	9 days	Fri 11/19/04
50		Alternative solutions	9 days	Fri 11/19/04
51		Feasibility study	9 days	Fri 11/19/04
52		Task Specifications	9 days	Fri 11/19/04
53		Preliminary Design	9 days	Fri 11/19/04
54		Method of approach	9 days	Fri 11/19/04
55		Christian perspective	9 days	Fri 11/19/04
56		Task Breakdown/ Time schedule	9 days	Fri 11/19/04
57		Cost Estimates	9 days	Fri 11/19/04
58		**Refine PPFS rough draft, finalize**	7 days	Fri 12/3/04
59		**Budgets**	**124 days**	**Mon 11/29/04**
60		Update November Budget	1 day	Mon 11/29/04
61		Update December Budget	1 day	Fri 12/10/04
62		Update January Budget	1 day	Fri 1/28/05
63		Update February Budget	1 day	Fri 2/25/05
64		Update March Budget	1 day	Wed 3/30/05
65		Update April Budget	1 day	Fri 4/29/05
66		Update May Budget	1 day	Mon 5/16/05



Critical		Split		Baseline Milestone		Project Summary	
Critical Split		Task Progress		Milestone		External Tasks	
Critical Progress		Baseline		Summary Progress		External Milestone	
Task		Baseline Split		Summary		Deadline	

Project: Project Schedule.mpp
Date: Mon 2/7/05

ID		Task Name	Duration	Start
67		**Web Page Design**	**22 days**	**Fri 11/12/04**
68	✓	Learn Dreamweaver	8 days	Fri 11/12/04
69	✓	Begin Formatting Template	12 days	Tue 11/16/04
70	✓	Finish Template	5 days	Thu 12/2/04
71		Post PPFS to Webpage	1 day	Fri 12/10/04
72		**FEA Analysis**	**20 days**	**Wed 1/5/05**
73		Learn FEA Program	20 days	Wed 1/5/05
74		FEA Frame Analysis	12 days	Sat 1/15/05
75		Joint/Connection Analysis	12 days	Sat 1/15/05
76		**Prototyping**	**70 days**	**Wed 1/12/05**
77		**Preliminary Prototypes**	**17 days**	**Wed 1/12/05**
78		Build Wood Prototype of ORU Wheelchair	3 days	Wed 1/12/05
79		Wood Construction of Prototype	4 days	Thu 1/27/05
80		**Order Materials for Prototype**	**40 days**	**Fri 1/21/05**
81		Search for Wheel Donations	7 days	Fri 1/21/05
82		Steel Donations	7 days	Fri 1/21/05
83		Fabric Donations	7 days	Fri 1/21/05
84		**Prototype (First Cut)**	**26 days**	**Wed 2/9/05**
85		Frame Construction	20 days	Wed 2/9/05
86		Wheel/ Axle Construction	10 days	Mon 2/28/05
87		Brake Assembly	3 days	Thu 3/10/05
88		Seat Fabrication	3 days	Mon 3/14/05
89		**Prototype (Final)**	**10 days**	**Mon 4/4/05**
90		Re-work Weak Areas from Initial Prototype	10 days	Mon 4/4/05
91		**Oral Presentations**	**160 days**	**Wed 10/13/04**
92	✓	Initial Oral Presentation	3 days	Wed 10/13/04
93	✓	Second Oral Presentation	6 days	Mon 11/22/04
94		Third Oral Presentation	6 days	Mon 2/7/05
95		Final Oral Presentation	12 days	Wed 5/4/05
96		Final Report	85 days	Tue 1/18/05
97		Mission Trip	8 days	Mon 3/28/05



Project: Project Schedule.mpp
Date: Mon 2/7/05

Critical	Split	Baseline Milestone	Project Summary
Critical Split	Task Progress	Milestone	External Tasks
Critical Progress	Baseline	Summary Progress	External Milestone
Task	Baseline Split	Summary	Deadline

Appendix C

Refined Task Specifications

1) Overview

a. Feasibility Study (PPFS)

   i. Material availability- If parts break, replacements must be available within the country the wheelchair is shipped to. There is also potential for wheelchairs to be manufactured in the third world countries they will be sent to. (30 hours)

      1. Find direction from Phil Yocum
      2. Start digging for common materials
      3. Find Cost information
      4. Shipping availability with regard to Ghana
      5. Cost of products in America VS Ghana

   ii. Cost analysis- Is it possible to be within budget? (80 hours)

      1. Find donations for prototyping
      2. Work with suppliers for bulk ordering prices

   iii. Assembly process- We need to design a frame that can be constructed in the prisons. (30 hours)

      1. Determine manufacturing capabilities for Wheels for the World
      2. Current design-Labor Cost/Chair -- New Design / Time savings --costs efficiency improvement

   iv. Cultural considerations- What is appropriate within the various cultures the wheelchairs will be incorporated into? (10 hours)

b. Project Proposal

   i. Cost analysis- Can we meet the strict budget requirements that have been given to us? (10 hours)

      1. Set all deadlines in Microsoft Project

2) Final Design

a. Brainstorming- What are some various types of frame designs? What are the most important elements of the wheelchair? How do we begin coming up with a good design? (10 hours)

      1. Sketch multiple preliminary designs
         a. Frame / Wheels / Seat / Brakes (3 hours)
      2. Come up with a cost effective design and robust design
      3. Determine optimum design using trade-offs and decision matrix (3 hours)

ii. Preliminary design- Combining research to decide on an optimum design.
   1. Inventor drawings of overall design and subcomponents (30 hours)
   2. Stress Strain Calculations(30 hours)
   3. Failure analysis (12 hours)
   4. Design review with professor to discuss alterations and robustness of our design (5 hours)

iii. Material Selection- What kind of material can we use that will be cheap, light, and available in third world countries. (10 hours)
   1. Find a party to donate necessary materials for a prototype

3) Construction

a. Ordering of materials (5 hours)

b. Building prototype

   i. Build Desired Components (40 hours)
      1. Fabricate Frame
      2. Fabricate mounting Brackets
      3. Fabricate axles

   ii. Assembly of components (12 hours)

4) Class Assignments

a. Presentations

   i. Oral presentation for class- This is the second presentation of the semester. (10 hours)

   ii. Oral presentation for class- This is the first presentation of the second semester. (10 hours)

   iii. Final presentation for class- The final presentation before senior design banquet. (18 hours)

b. Prelim. Evaluation of Feasibility; Preliminary Budget

c. Refined Task Specs

d. Preliminary Project Schedule

Appendix D
Team 8 Budget

Wheelchair Cost Estimate[1]			
Component	**Qty**	**Cost (ea.)**	**Total**
Frame			
Steel/Aluminum tubing			$30.00
Fasteners			$5.00
Wheel Assemblies			
Rear Wheel/Tire	2	$10.00	$20.00
Front Wheel/Tire	1	$10.00	$10.00
Locking Mechanism	2	$13.20	$26.40
Bushings			$6.00
Axle	2	$2.00	$4.00
Seat Assembly			
Fabric	2	$2.50	$5.00
Comfort			
Footrest	1	$5.00	$5.00
Armrest	2	$7.50	$15.00
Hand Grips	2	$1.00	$2.00
Manufacturing			
Heavy Duty Thread	1	$0.25	$0.25
Welding wire/rod	1	$7.50	$7.50
Paint/Powder Coat	1	$7.50	$7.50
Total			$143.65

[1] Estimate obtained using wholesale prices from http://www.edmond-wheelchair.com/ and referencing an Oral Roberts University cost estimate

Appendix E
Wheelchair Component Outline

I. Frame

- **a.** Metal Tubing
- **b.** Square Tubing

II. Wheel Assembly

- **a.** Rear Wheel Assembly
  - **i.** Tire
  - **ii.** Tube
  - **iii.** Wheel
  - **iv.** Handle
  - **v.** Bushings
  - **vi.** Axle
  - **vii.** Fasteners
- **b.** Front Wheel Assembly (hopefully pre-assembled)
  - **i.** Tire?
  - **ii.** Tube?
  - **iii.** Fasteners
- **c.** Locking Mechanism
  - **i.** 4 bar linkage (hopefully pre-assembled)
    - **1.** Metal components
    - **2.** Fasteners

III. Seat

- a. Butt support
  - **i.** Fabric
  - **ii.** Cushion
  - **iii.** Fasten/secure
- **b.** Back support
  - **i.** Fabric

IV. Comfort

- **a.** Armrest
  - **i.** Fabric
  - **ii.** Padding
- **b.** Footrest
  - **i.** Platform
  - **ii.** Grip?
  - **iii.** Fasteners
- **c.** Handles
  - **i.** Pre-assembled grip

V. Manufacturing Costs

- **a.** Sewing material
- **b.** Welding material
- **c.** Paint/Coating