Abstract: The Stocker Center Street Gang was faced with a challenge to assist people with disabilities to enter into or advance in the workplace. After discussion with customers, it was decided to improve on torque augmenting wheelchairs for the purpose of overcoming obstacles. By easing mobility issues, people who are confined to wheelchairs are empowered with independence in and on the way to the workplace. Ramps were measured and compared to the Americans with Disabilities Act standard 1:12 ramp. A ramp of 1:5.1 was found to be the maximum reasonable ramp one could expect to overcome. The final wheelchair design will be a mechanical gearing solution able to make a 1:5.1 ramp as easy to climb as a 1:12 ramp. This design will be achieved and the final prototype will be lighter, less expensive, and more maintainable than similar products commercially available.
1.0 Introduction

“Senior Design is a year-long course that will provide a comprehensive, capstone experience for mechanical engineering majors. The course includes analytical techniques of design, as well as the design, construction, and evaluation of the performance of an actual engineering system” (ME 470). In the 2007-2008 academic year, senior design teams will be designing assistive technology devices to allow people with disabilities to enter into or advance in the workplace, per the NISH (National Industries for the Severely Handicapped) National Scholar Award for Workplace Innovation contest.

1.0.1 Background:

Disability is a challenge that many Americans will face in their lifetimes. According to the latest U.S. Census estimate, more than 51.2 million people in the United States have a disability, of which, over 30 million were between the ages of 21 and 64 (Americans with Disabilities). Additionally, approximately 1 in 7 people can expect to be disabled five years or more before retirement (Commissioners). Workplace injuries are not the primary cause of disability. Ninety percent of disabling injuries are not work-related (National Safety Council). One out of two hundred fifty Americans are confined to a wheelchair today. Ten thousand people every year sustain a spinal cord injury (Disability Statistics).

People with disabilities struggle in the workplace. Only 58% of Americans with disabilities have jobs; America is ranked 12th in the industrial world for employing people with disabilities (NationMaster). The average workplace absence for a disabling injury is two and a half years (Commissioners). This is a compounding hardship in the lives of people with disabilities. While they are paying for care for their injuries or for assistance with their disabilities, they are less able to make money to help ease the burden of this cost.

NISH is one organization that is assisting people with disabilities in the workplace. NISH is one of three agencies that work through Federal Ability One Program contracts which are aimed at helping individuals reach their full potential. The funding goes toward creating employment opportunities for people with disabilities. Currently 48,000 people are employed through Ability One with over 600 community Non-Profit Associations participating (NISH 2007).

NISH also supports incentives in the technical, engineering, financial, and legal sectors to assist people with disabilities. The National Scholar Award for Workplace Innovation and Design is one such incentive. Participation in this competition is the purpose of the 2007-2008 mechanical engineering senior design projects. The goal of the award is to creatively eliminate barriers restricting people with disabilities from entering into or advancing in the workplace. It requires a functioning device and report presented by April 11, 2008.

A Working prototype must address one of the seven NISH topic areas:
1. Technology for Special Populations
2. Augmentative and Alternative Communication
3. Computer Access and Use
4. Environmental Accommodation
5. Functional Control and Assistance
For consideration in the national competition the device must be developed in coordination with a person with a disability. Consultation with an NISH representative is highly recommended.

The last two NISH award winners were as follows:

2006-2007: “Universal Box Taping Device”
   It was developed by the South Dakota School of Mines in coordination with BH Services, Inc. It allowed people with limited coordination and range of motion to seal boxes. It increased employee independence and productivity.

2005-2006: “Tag Stamping Device”
   It was developed by Rose Hulman Inst. Of Tech. in coordination with Knox County ARC. It is used to stamp lot numbers on clothing tags and it assisted employees with limited upper body range of motion or tremors. It increased employee productivity and chance to earn higher wages.

NISH maintains relationships with many organizations that are committed to assisting people with disabilities in the workplace. Service Source, Inc. in Alexandria, VA was established in 1972 and provides labor to commercial government sectors. It is the largest community rehabilitation program in Virginia. In 2002, they supplied jobs to 1800 people with disabilities. They have a large range of business services and federal contracts including mailroom operations for the EPA, U.S. Dep. of Transportation, and U.S. Dep. of Commerce; Food service for several branches of the U.S. military (full cooking and cleaning); and Keep it Green, a computer hardware recycling management group (ServiceSource 2007).

Goodwill Industries helps people overcome disability and condition barriers in order to obtain employment and participate in the community. They find and train employees to fulfill outsourced business tasks such as packaging, assembly, mailing, data entry, custodial work, and grounds-keeping. They work with the federal agency the Naval Air Warfare Center to provide mail, requisitioning, and warehouse services (Goodwill 2007).

SOC Enterprises in Arlington, Virginia employs 300 people with disabilities annually in jobs such as printing, mailroom services, photocopying, and binding. They work with the FDA, the U.S. Patent Office, and the Army Corps of Engineers, among others. They have been the leader in disaster preparedness in affiliation with NISH including evacuation procedures and emergency planning when people with disabilities are involved and mailroom issues such as bio-terrorism. They emphasize “self-improvement, advancement, acceptance, and monetary reward in a safe environment” (SOC Enterprises 2007).

Several non-NISH affiliated companies employ people with disabilities and are near the Athens community. One of which is Atco, Inc. – Personnel Plus founded in 1983 and located in Athens, Ohio. Atco helps place people with disabilities in the workforce around the community and has several in house tasks that are suitable for people with disabilities. This is a highly accredited organization. The current staff has received numerous awards for their work with the community in finding employment for people with disabilities. In 2005, Atco accomplished a 100% job retention rate for their placed employees. Atco has over 66 employees working in over 50 area businesses, as of October, 2007. Their longest placement is 21 years. The company
provides the community with a win-win situation because the businesses can fill entry level positions with quality employees and the placed employee enjoys a higher quality of life (Personnel Plus 2007).

Wal-Mart is another non-NISH affiliated association that works with several organizations to hire people with disabilities including: American Association of People with Disabilities, Asian Rehabilitation Services, Goodwill Industries, National Business and Disability Council, National Organization on Disability, Wheelchair Foundation, World Institute on Disabilities, and People with Disabilities Associate Resource Group. For the third year in a row, Wal-Mart was recognized as one of the 2006 top companies in the nation for providing a positive working environment for people with disabilities according to a poll sponsored by Career and the Disabled Magazine (Walmart 2007).

The Office for Institutional Equity is one more non-NISH affiliated association. The Office for Institutional Equity works to create an environment that is respectful and inclusive for all people at Ohio University. It ensures that the university complies with federal, state and institutional laws and has policies that support a non discriminatory environment. The Office for Institutional Equity offers training with regards to accessibility, affirmative action and discrimination. The Office of Disability Services is a part of the Office for Institutional Equity. The Office of Disability Services facilitates services and provides reasonable accommodations for people with disabilities in order to make Ohio University programmatically and architecturally accessible. It offers confidential consultation about disability questions and concerns for all members of the campus community. It is the policy of Ohio University to ensure individuals with disabilities equal opportunity in employment and promotion by means of reasonable accommodation consistent with Sections 502, 503, and 504 of the Rehabilitation Act of 1973 and the Americans with Disabilities Act of 1990. The Ohio University Crewson House is the home of OU Disability Services which is located west of Chubb Hall, on the corner of South Court and West Mulberry Streets (OIE 2007).

1.0.2 Purpose:

People with disabilities have financial needs that are equal to if not greater than able-bodied Americans and therefore need to be able to find work despite their disabilities. Assistive technology provides one type of solutions for such people.

People with disabilities need assistance to make themselves functional on a scale similar to non-disabled people and thereby make their world more equitable and fair. In “Your little doorstep is my wall: A personal experience of living in a disabling society,” Anders Lofgren argues that there is a discrimination against people with disabilities in all parts of our society. She defines it as ablism (267-271).

The purpose of this project is to provide a creative solution that can assist a person with a disability in their workplace and/or career pursuits.

1.0.3 Scope:

The scope of this project will encompass the following parameters:

1. This project will design, develop, construct, test, and analyze an assistive technology device to assist a person with a disability to enter into or advance in the workplace.
2. This team will work with a person with a disability in the Athens community.
3. A functional, deliverable prototype will be available to the community member at the end of the project.
4. The solution will be limited to primarily mechanical systems.
   a. Basic Electronics may be necessary but complex electrical systems such as microcontrollers, signal processing, and advanced logic are outside the scope.
5. The solution must be within reasonable limits of cost, time, and lab resource usage.
   a. The team has a spending limit of $2,000
   b. A working prototype must be completed by April 11, 2008

1.0.4 Objectives:

This team strives to the following goals and objectives:

1. Make a positive impact on individuals with disabilities and society.
2. Make decisions with the business perspective in mind.
3. Do sufficient research to fully understand the problem and the market for solutions.
4. Use creativity to invent or improve a mechanical system to enhance the workplace environment for people with disabilities.
5. Submit the design for the NISH award.
6. Provide a working, deliverable prototype to the individual that assists with the project.
7. Provide an effective report of all actions during the design process.
8. Improve technical, team, leadership, management, and business skills with the goal of being ready for the professional world.

1.1 Needs Statement

For a successful project, an engineering solution for the following needs statement must be developed:

“There is a need for assistive technology devices that reduce barriers that prevent persons with severe disabilities from entering or advancing in the workplace. Devices are needed to address environmental accommodation, functional assistance, and mobility issues for people with cognitive disabilities, developmental disabilities, and physical impairments (vision, hearing and mobility)” (NISH 2007).

1.1.1 Introduction to the Stocker Center Street Gang’s project focus.

The team considered several possible problems for people with various disabilities, including: tremors, trouble serving food, inability to perform grounds keeping effectively, and various mobility problems.

Several individuals in manual wheelchairs were found that need mobility assistance, especially on ramps. This drove the team to select a project to develop a device to make ramp climbing less difficult.
2.0 Customer Needs Assessment

Table 2.0.1 outlines the needs of a torque enhancing wheelchair. This customer needs list was generated from group discussions and then submitted to customers for their input. The customers replied with feedback which the group used to improve and/or support the needs. Below is the list that was agreed upon by both customers and the team:

Table 2.0.1: Initial Customer Needs List from Customer and Group Discussions

<table>
<thead>
<tr>
<th>Reliability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Easy maintenance</td>
</tr>
<tr>
<td>Regenerative Braking</td>
</tr>
<tr>
<td>Aesthetics</td>
</tr>
<tr>
<td>Weight</td>
</tr>
<tr>
<td>Safety</td>
</tr>
<tr>
<td>Recharge Time</td>
</tr>
<tr>
<td>Range</td>
</tr>
<tr>
<td>Maneuverability</td>
</tr>
<tr>
<td>Ramp/Grade Accessible</td>
</tr>
<tr>
<td>Environmental Resistance</td>
</tr>
<tr>
<td>Learning period</td>
</tr>
<tr>
<td>Portability</td>
</tr>
<tr>
<td>Ergonomics</td>
</tr>
<tr>
<td>Cost</td>
</tr>
<tr>
<td>Durable</td>
</tr>
</tbody>
</table>
Table 2.0.2: Hierarchal Customer Needs List

<table>
<thead>
<tr>
<th>Needs</th>
<th>Weighting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety</td>
<td>10</td>
</tr>
<tr>
<td>1.1 No sharp or rough edges</td>
<td></td>
</tr>
<tr>
<td>1.2 Brakes</td>
<td></td>
</tr>
<tr>
<td>1.3 Low Center of Gravity</td>
<td></td>
</tr>
<tr>
<td>Reliability (9)</td>
<td></td>
</tr>
<tr>
<td>2.1 Not leave user stranded</td>
<td></td>
</tr>
<tr>
<td>2.2 Runs to specifications</td>
<td></td>
</tr>
<tr>
<td>Ramp/Grade Accessible (9)</td>
<td></td>
</tr>
<tr>
<td>3.1 Able to climb ramps without exerting energy of customer beyond a comfortable level</td>
<td></td>
</tr>
<tr>
<td>Cost (9)</td>
<td></td>
</tr>
<tr>
<td>4.1 Cost should not be prohibitive to customer’s needs</td>
<td></td>
</tr>
<tr>
<td>Easy Maintenance (8.5)</td>
<td></td>
</tr>
<tr>
<td>5.1 Customer able to perform maintenance by themselves</td>
<td></td>
</tr>
<tr>
<td>5.2 Easy to understand instructions</td>
<td></td>
</tr>
<tr>
<td>Ergonomics (8.5)</td>
<td></td>
</tr>
<tr>
<td>6.1 Comfortable seating</td>
<td></td>
</tr>
<tr>
<td>6.2 Easy access to adjustments</td>
<td></td>
</tr>
</tbody>
</table>

2.1 Weighting of Customer Needs

The needs of the customer have varying importance and these needs were rated on a 10-point scale with 10 being the most important. This table is an initial assessment from the team. Feedback from the customer in response to this list is shown in Section 6.2.1.

Table 2.1.1: Customer Need Weights

<table>
<thead>
<tr>
<th>Needs</th>
<th>Weighting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety</td>
<td>10</td>
</tr>
<tr>
<td>Reliability</td>
<td>9</td>
</tr>
<tr>
<td>Ramp/Grade Accessible</td>
<td>9</td>
</tr>
<tr>
<td>Cost</td>
<td>9</td>
</tr>
<tr>
<td>Easy maintenance</td>
<td>8.5</td>
</tr>
<tr>
<td>Ergonomics</td>
<td>8.5</td>
</tr>
<tr>
<td>Durable</td>
<td>8.5</td>
</tr>
<tr>
<td>Portability</td>
<td>7.5</td>
</tr>
<tr>
<td>Range</td>
<td>7</td>
</tr>
<tr>
<td>Lifespan</td>
<td>7</td>
</tr>
<tr>
<td>Environmental Resistance</td>
<td>6.5</td>
</tr>
</tbody>
</table>
2.2 Plan for Ongoing Customer Involvement

The next step in customer research will be to develop a stronger and more diverse base of customers over winter break. The following form will be given to these additional customers to seek input to improve our project. This customer questionnaire appears in Figure 2.1.1.

![Customer Needs Questionnaire](image)

Figure 2.2.1: Initial Customer Questionnaire

As the project progresses, updates will be written for the customers to keep them informed and to allow them to provide additional feedback. The updates will include pictures/sketches, explanations, etc. in the form of documents that can be emailed. The next update will show the selected concept including a discussion of why that concept is desirable and to allow for customer feedback. The goal is to complete enough work to provide updates monthly.
3.0 Revised Need Statement and Target Specifications

This section of the report defines the specific problem that this project addresses and creates a guide from which the final concept and design will be built. The final concept can be justified if it properly solves the focus need while still conforming to customer and standard specifications.

3.1 Concise Need Statement

There is a need for torque converting wheelchairs for people confined to a wheelchair that want to maintain their upper-body strength through the use of a manual wheelchair, but occasionally need additional torque to maneuver workplace obstacles. Even if a workplace complies with the Americans with Disabilities Act (ADA) standards, it may still be difficult for an employee confined to a wheelchair to get to their work station. Rather than carrying around a large, heavy system, an alternative should be designed that will allow for increased torque without significant increased weight. Some circumstances that require more torque are listed below.

3.1.1 Circumstances That Require More Torque

- Ramps or hills that are too steep
- Large bumps to overcome
- Soft terrain
- Rough or unlevel surfaces
- Carrying heavy loads
- Traveling long distances
- Weak upper-body strength

3.2 Solution Specifications

A valid concept and design must meet the specifications listed below. Most are customer driven to ensure that the solution will satisfy the need, while others are based on standards of industry or tests/calculations that will allow the design to succeed.

3.2.1 Metrics

This will include each target specification and its measurement unit as shown in Table 3.2.1. Each specification will be given an acceptable range of values based on future research, testing and calculations. Each specification will also be rated by importance to insure proper attention in the final design.
<table>
<thead>
<tr>
<th>Metric</th>
<th>Units</th>
<th>Value</th>
<th>Justification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safe</td>
<td>pass/fail</td>
<td>pass</td>
<td>- Must meet or exceed all ANSI/RESNA WC Vol. 1 &amp; 2 standards for safety</td>
</tr>
<tr>
<td>Enhances Human Force</td>
<td>ramp angle</td>
<td>11.1° = 4.8°</td>
<td>- Make the very difficult 11.1° ramp feel like an ADA approved 4.8° ramp</td>
</tr>
<tr>
<td>1. Wheelchair Torque</td>
<td>ft - lbs.</td>
<td>10.94</td>
<td>- Additional Torque necessary to make 11.1° ramp feel like an ADA approved 4.8° ramp</td>
</tr>
<tr>
<td>2. Geared wheelchair</td>
<td>gear ratio</td>
<td>2.32:1</td>
<td>- Gearing required to make 11.1° ramp feel like an ADA approved 4.8° ramp</td>
</tr>
<tr>
<td>Cost</td>
<td>$</td>
<td>2000</td>
<td>- Approximate amount of available funding, and still over 50% less than the majority of available products.</td>
</tr>
<tr>
<td>Lightweight</td>
<td>lbs</td>
<td>15 - 35</td>
<td>- A mechanical addition should be ~ 15 lbs. &amp; an electric assist should be ~ 35lbs. based on benchmarked products</td>
</tr>
<tr>
<td>Durable</td>
<td>pass/fail</td>
<td>pass</td>
<td>- Must meet or exceed all ANSI/RESNA WC Vol. 1 &amp; 2 standards for testing</td>
</tr>
<tr>
<td>Reliability</td>
<td>warranty</td>
<td>2 years</td>
<td>- Most power-assist wheelchairs come with a 24 month limited warranty with a base-by-base accident clause</td>
</tr>
<tr>
<td>Range per Charge (if battery powered)</td>
<td>miles</td>
<td>10</td>
<td>- Consistent with existing products and battery capabilities without adding unnecessary weight</td>
</tr>
<tr>
<td>Compact</td>
<td>in</td>
<td>&lt; 3</td>
<td>- No more than additional 3 inches in width at each wheel hub based on current products and door widths (~33&quot;)</td>
</tr>
<tr>
<td>Maintains same level of maneuverability</td>
<td>pass/fail</td>
<td>pass</td>
<td>- Must maintain zero-turn-radius to stay fully functional in and out of workplace</td>
</tr>
</tbody>
</table>

**Table 3.2.1: Target Specifications-Metrics**

Good

OK, but it seems that minimizing this is important. Maybe include as a criteria also.
3.2.2 Criteria
Criteria are features that should be in the design if possible, but are not a requirement.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foldable</td>
<td>- The wheelchair should maintain its ability to fold and should fit in the trunk of a typical vehicle for ease of transportation</td>
</tr>
<tr>
<td>Retrofit kit</td>
<td>- The wheelchair enhancement should come in a retrofit kit that allows any existing wheelchair to be adapted with a torque-assist feature without purchasing a new chair</td>
</tr>
<tr>
<td>Aesthetically pleasing</td>
<td>- The wheelchair should be visually appealing and marketable to the public without bulky, awkward additions</td>
</tr>
<tr>
<td>Ergonomics</td>
<td>- Comfort and reduction in fatigue should be highly considered to keep the user satisfied throughout the work day</td>
</tr>
<tr>
<td>Environmental Resistance</td>
<td>- The materials and construction of the wheelchair should resist the elements of nature over long periods of time</td>
</tr>
<tr>
<td>Low resistance in non-assist mode</td>
<td>- Any resistance in direct drive (non-assist mode) of the wheelchair should be an absolute minimum, and negligible to the user</td>
</tr>
<tr>
<td>Easy Maintenance &amp; Assembly</td>
<td>- The wheelchair user should have access to fix minor repairs with standard hand tools while in chair</td>
</tr>
</tbody>
</table>

4.0 External Search

4.0.1 Interview with Dr. Carolyn Lewis

I. Dr. Carolyn Lewis
   A. Works for the news station WOUB
   B. Confined to a wheelchair as a result of an injury
      1. Can stand, but cannot walk

II. Discrimination
   A. Cannot get out of her building in the event of a fire without assistance
      1. If a connecting door to Old Baker Center was unlocked she would be able to get out.
   B. Trouble negotiating campus and town: bathrooms and Cutler hall
      2. Often told that something will be done, but there is no money
   C. People ignore her, for example, waiters and waitresses at a restaurant will ask her friends what she wants to order
   D. Must call to confirm that she has a handicap accessible room in hotels
      1. Often she is told that she has an accessible room only to discover that, for example, the room has a tub instead of a roll in shower
2. She said, “When you go to check in somewhere or do something, things that are supposed to be right, aren’t because an able bodied person doesn’t think about it.”
3. Even rooms that are supposed to be accessible aren’t: the iron, electrical outlets and the thermostat can’t be reached.

E. New Baker Center didn’t have theater seats for people in wheelchairs until she complained.
1. There were also no automatic door openers to the restrooms.

III. Helpful devices
A. Ramps
1. Help a person in a wheelchair the most for getting in and out of buildings.
2. Often too steep of an incline.
   a. Can’t use ramp to her building because it’s too steep.
   b. When the ramp from the Cat Cab comes down, it might be too steep.
      depending on what it comes down on; For Example, it may come down on the sidewalk or another surface that puts it at an angle.
3. Ramps that require you to change directions can cause you to scrape your hands or arms on corners.
4. Some buildings don’t even have ramps like Cutler Hall or bad ramps like Alden Library, it zigzags too much to be useable.

B. Well designed restrooms
1. Many restrooms have items out of reach.

C. Workspace and desk area
1. Computer set up must be ergonomically correct.
2. Enough space to maneuver.
3. Things need to be at your level and reachable.
4. Small desk or a curved desk that would be built for a wheelchair to make things easier to reach.
5. Something under the desk for resting feet.
6. Uses grabber because she’s often knocking things over.
   a. Cup holder.

D. Reachable shelving unit
1. Existing units are too high.
2. Agreed that a pull down or movable shelves would be helpful.

IV. Restrictions from her current chair, which is manual.
A. Places where you just can’t go
1. Spaces are too narrow to get through.
2. They push her down the aisle of an airplane in a tiny aisle chair.
3. Cab drivers don’t want to go out of their way to help.

B. Motorized chairs do more
1. Some have seats to lift you.
2. Can go on gravel or grass, where a manual chair has difficulties.
3. Can go up ramps by yourself more easily; manual wheelchairs require that you exert a lot of energy.
4. Thought about getting a motorized chair, but decided against it to keep arm and upper body strength.
C. Nowhere to put anything
V. Designing her perfect chair
   A. Good seat: current seats are thin and wear out quickly
   B. Wishes it wasn’t so big and cumbersome
   C. Wishes it had a motorized option
      1. Is manual when she wants too and have motor when she needs it
         a. Needs it for times like ramps when she can’t get up
         b. Doesn’t want the big box like on the motorized wheelchair
            i. Motorized chairs don’t fold, but the manual does
         c. Doesn’t need the power of a big electrical chair
      2. Can move through big places like the airport. Also help in travel, work and
         places that are difficult to negotiate
      3. Manual would be default and the motorized would be secondary
      4. “Hybrid” with the battery recharging when it rolls

4.1 Benchmarking

Several features from products that address the project needs and are currently
commercially available were compared. The features that were picked were those that had the
most impact on the design. As shown in Table 4.1.1 all the products are well above the $1,000
mark with many products nearing $5,000. Power-assist products range from 10 to 60 pounds of
added weight, with the mechanical options adding considerably less. Safety standards limit the
max speed of any wheelchair to 4 mph. A battery life of 10 miles on one charge is typical. The
different wheelchair products offer a varying range of additional assistance. From the table,
approximately 50% additional force to the user’s input is a comparable starting point for
overcoming difficult obstacles.

Through benchmarking, four primary types of power-assist wheelchairs are identified.
The first type is a battery powered device that provides additional power through a motorized
wheel in contact with the ground as shown in Figure 4.1.1. In the table, this drive method is
referred to as ground friction. This type of power-assist is easily adaptable with any wheelchair,
but can be expensive and heavy. An added ground friction device limits the transportability of
the wheelchair. The second type is a wheelchair fitted with specialized wheels that have battery-
powered motorized hubs as shown in Figure 4.1.2. Controls in the wheels can monitor input and
increase power by up to 80% while simultaneously adjusting to compensate for balance. The
controls systems of electric hubs are very complex and require industry technicians to perform
regular maintenance. The third type uses a similar hub, but in this case, the hub is a system of
mechanical gears that allows the user to shift between high and low gear. It is shown in Figure
4.1.3. The advantages of a geared chair are increased durability and freedom from heavy, short-
lived batteries. The Magicwheels chair features a high, direct drive gear, and a low, 2 to 1 gear,
for normal use and climbing steep grades respectively. Wheelchairs with mechanical enhancing
systems are more appropriately identified as torque assist or torque converting than power-assist
wheelchairs. The fourth type identifies a torque converting wheel system that uses a lever arm
attached to a precision gear box in the wheel hub as shown in Figure 4.1.4. The levers and gears
of the two wheels amplify a users input by up to 45%. Identifying these four categories of
power-assist or torque converting wheelchairs is a critical milestone for creating an original
solution.

13
<table>
<thead>
<tr>
<th>Name</th>
<th>Rating</th>
<th>Price</th>
<th>Features</th>
<th>Description</th>
<th>Notes</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smithsonics.com</td>
<td>3</td>
<td>$120</td>
<td>Manual, digital</td>
<td>Quick release</td>
<td>Geared Drive</td>
<td>Good</td>
</tr>
<tr>
<td>JohnDoes.com</td>
<td>4</td>
<td>$250</td>
<td>Manual, digital</td>
<td>9-speed</td>
<td>2-speed</td>
<td>Poor</td>
</tr>
<tr>
<td>JaneDoe.com</td>
<td>2</td>
<td>$100</td>
<td>Manual, digital</td>
<td>Quick release</td>
<td>Geared Drive</td>
<td>Mixed</td>
</tr>
</tbody>
</table>

Table 4:41: Benchmarks of Similar Products That Are Commercially Available (1)
Figure 4.1.1: Samson PD4 Wheelchair Add-on (Samson PD4)

Figure 4.1.2: Alber E-motion Wheels (E-motion)
Figure 4.1.3: Magicwheels 2-gear wheelchair (Magicwheels)

Figure 4.1.4: Superquad Wijit (wijit)
4.2 Applicable Patents
The following are a variety of patents that address the same or similar problems to this project’s needs statement.

1. U.S. Patent 6880653, “Drive Unit of Electric Vehicle,” describes a wheelchair or similar vehicle (see Figure 4.2.1) driven by an electric motor equipped with a geared drive mechanism. A planetary gear rotates with a sun and ring gear to drive an output shaft at a particular reduction ratio. A switching mechanism is used to keep the vehicle in forward or reverse gear (Kanno, 2005).

![Figure 4.2.1: Drive Unit of Electric Vehicle](image)

2. U.S. Patent 6860347, “Wheelchair Drive Unit,” describes a wheelchair attachment (see Figure 4.2.2) that provides additional power by means of frictional contact with the ground. The unit is a drive wheel attached between the rear wheels of the chair’s frame by clamps. The wheelchair uses an electric motor with a speed reduction device to push the chair. A clutch allows the drive assist to be disengaged. The unit also includes “pressurization of gear works” and a debris free housing (Sinclair and Kalogroulis, 2005).
3. U.S. Patent 6354390, “Power Assisted Wheelchair,” describes a wheelchair capable of being manually driven while simultaneously being aided by an electric motor (see Figure 4.2.3). This wheelchair is equipped with advanced control systems capable of identifying the amount of input force and varying its power-assistance accordingly. “Assist is greater at low speeds, and less at high speeds.” The wheelchair is able to identify excessive high speeds and apply a brake automatically to the wheels (Uchiyama and Ogata, 2002).
4. U.S. Patent 6015021, “Electrically Assisted Vehicle,” describes a drive mechanism (see Figure 4.2.4) that utilizes both human driving force and additional power assistance from an electric motor. The unit uses a torque detection control system that senses human input and applies a calculated reduction ratio to assist the vehicle’s movement. The control system and auxiliary motor are battery powered (Tanaka and Suhara, 2000).

![Electrically Assisted Vehicle Mechanism](image)

**Figure 4.2.4: Electrically Assisted Vehicle Mechanism**

5. U.S. Patent 5495904, “Wheelchair Power System,” describes a wheelchair power system that is foldable, quick releases from the axles, and mountable without tools (see Figure 4.2.5). The wheelchair has two drive units, one for each wheel, that attach to the frame by mounting brackets that must be supplied. The wheelchair has a “tray” to house the batteries, and a control system that monitors power to the two drive units. “The power system is retrofittable to existing wheelchairs, and is designed for easy removal” (Zwaan and Nyberg, 1996).
6. U.S. Patent 5222597, “Power Assist Device for a Wheelchair,” describes a wheelchair power assist mechanism (see Figure 4.2.6) that uses frictional contact with the ground to help push the chair. The device has a drive wheel that can be lowered and raised from the ground depending on whether or not it’s being utilized. The unit includes two motors, one for powering the drive-wheel in contact with the ground and the other for raising and lowering the unit. A manual switch allows a control system to initiate the power assist mode by the user whenever extra assistance is needed (Broadhead and Hobson, 1993).
7. U.S. Patent 6893035, “Wheelchair Drive Mechanism,” describes a wheelchair (see Figure 4.2.7) design sold by a company called Wijit. The wheelchair has lever arms that are connected to a precision gear train in the wheel hub. The mechanism only grips when force is applied in the forward direction and the system amplifies the input by 45% (Watwood and DeJong, 2005).
8. U.S. Patent 6805371, “Two-speed Wheel Assembly for Manual Wheelchairs,” describes the patented “hypocycloidal gear” (see Figure 4.2.8) featured on the chairs manufactured by Magicwheels, Inc. The wheels have a quick release attachment capable of fitting most standard wheelchairs. The wheels have a direct drive gear for normal use and a 2:1 gear ratio for climbing steeper terrain. The gears are maintained in a debris free wheel hub, and the shifting mechanism is integrated to the outer cover of the wheel (Meginniss and Matas, 2004).

![Figure 4.2.8: Magicwheels 2-speed Gear](image)

9. U.S. Patent 5184837, “Wheelchair,” describes a wheelchair (see Figure 4.2.9) capable of multiple speeds through the use of a geared hub. The wheelchair claims to allow users to traverse different grades more easily or at a faster rate than a standard manual wheelchair. The design specifically mentions the use of a Sturmey Archer type hub as the gearing mechanism (Alexander, 1993).

![Figure 4.2.9: Multi-speed Wheelchair with Geared Hub](image)
4.3 Applicable Standards

There are three organizations that have developed standards for wheelchairs. The three organizations are the American National Standards Institute/Rehabilitation Engineering and Assistive Technology Society of North America, the International Standards Organization and the Society of Automotive Engineers. ANSI/RESNA standards deal primarily with design requirements and test methods for wheelchairs. ISO standards provide minimum and maximum values for certain attributes of wheelchairs. SAE standards deal primarily with wheelchair restraints and safety during transportation in automobiles.

4.4 Applicable Constraints

Laboratory space is very limited. The space allotted for the project should be about the size of a wheelchair. Anything larger than the size of a manual wheelchair will need to be stored in a separate area. Also, as to not increase the size of the wheelchair, any bulky portions of the design will need to fit in the area under the seat of the wheelchair. The dimensions of this area are 18” x 18” x 19” for an overall volume of 6156 in³ (3.56 ft³). The budget for this project is currently set at $2,000. This project should be kept to an undergraduate level of design. The project should be chosen knowing that it must be completed by the submission deadline of April 11, 2008. The prototype developed must be marketable even though there is no plan for large-scale manufacturing. The product must comply with industry standards in order to ensure a safe, quality product.

4.5 Business Opportunity

There is a market for improvements in wheelchair technology because 1.6 million Americans who live outside of institutions are currently in a wheelchair (Kaye, 2002). Manual wheelchair users often encounter obstacles in their daily lives such as ramps or hills that are too steep to overcome. Despite these obstacles and the option of switching to an electric wheelchair, these users desire to keep their current chair to maintain their upper-body strength and by doing so maintain more independence. By adding a torque assistive device to a wheelchair, the user can increase his/her ability to conquer these obstacles. The primary market of this product would be people with weaker upper body strength such as females, older adults and those weakened because of a disability.

Many products are currently available that address the same need, generally using gearing or electric motors to decrease the force the user must apply. They are generally in the $4,000 to $6,000 range and 30lbs or more. Additionally, electric power-assist introduces issues such as battery life, recharge time, and excessive weight. Any added weight to the wheelchair is more weight that the user must move.

The Stocker Center Street Gang is developing a mechanical product to assist grade climbing, which uses lower tech gearing solutions to be lightweight and lower cost. Its target weight will be less than 10lbs and its target retail price will be $2000. Because it is a mechanical system, it will not have the speed of currently available electrical systems. A product that is effective, affordable, and lightweight can increase the independence of a user. This would be highly desirable for someone who is in a wheelchair to increase the quality of his/her life.
5.0 Concept Generation

Concept generation consisted of a brainstorming and sketching session with the entire team as well as individual members creating sketches outside of team meetings. As group members came up with concept ideas, they were discussed at group meetings. The following is a simple “Power Flow” diagram used to drive some of the conceptualization:

![Power Flow Map to Drive Conceptualization](image)

From this map, various devices were brainstormed to possibly solve the ramp problem.

5.1 Problem Clarification

A list of difficult ramps and hills was provided by the primary customer, Dr. Lewis, and their grades were measured, as shown in Table 5.1.1.
Table 5.1.1: Incline testing results in a manual wheelchair

<table>
<thead>
<tr>
<th>Rise (in)</th>
<th>Ramp length (in)</th>
<th>Angle (deg)</th>
<th>Rise : Run</th>
<th>Effort Level</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>31.5</td>
<td>360</td>
<td>5.02</td>
<td>1 : 11.4</td>
<td>borderline</td>
<td>Riverpark Blg. 36</td>
</tr>
<tr>
<td>34</td>
<td>322</td>
<td>6.06</td>
<td>1 : 9.4</td>
<td>difficult</td>
<td>Riverpark Blg. 34</td>
</tr>
<tr>
<td>20</td>
<td>188</td>
<td>6.11</td>
<td>1 : 9.3</td>
<td>difficult</td>
<td>New Life</td>
</tr>
<tr>
<td>12.5</td>
<td>144</td>
<td>4.98</td>
<td>1 : 11.5</td>
<td>manageable</td>
<td>Martzolff</td>
</tr>
<tr>
<td>16</td>
<td>144</td>
<td>6.58</td>
<td>1 : 8.7</td>
<td>difficult</td>
<td>Fenzel</td>
</tr>
<tr>
<td>16.5</td>
<td>180</td>
<td>5.26</td>
<td>1 : 10.9</td>
<td>manageable</td>
<td>Nelson 1</td>
</tr>
<tr>
<td>16.5</td>
<td>69</td>
<td>13.84</td>
<td>1 : 4.1</td>
<td>nearly impossible</td>
<td>Nelson 2</td>
</tr>
<tr>
<td>10</td>
<td>132</td>
<td>4.34</td>
<td>1 : 13.2</td>
<td>fairly easy</td>
<td>Nelson 3</td>
</tr>
<tr>
<td>30</td>
<td>156</td>
<td>11.09</td>
<td>1 : 5.1</td>
<td>very difficult</td>
<td>Pickering</td>
</tr>
<tr>
<td>13.5</td>
<td>1104</td>
<td>8.44</td>
<td>1 : 6.7</td>
<td>difficult</td>
<td>Jeff Hill</td>
</tr>
<tr>
<td>36</td>
<td>3840</td>
<td>6.46</td>
<td>1 : 8.8</td>
<td>fairly easy</td>
<td>Mem Aud</td>
</tr>
<tr>
<td>20</td>
<td>2004</td>
<td>6.88</td>
<td>1 : 8.3</td>
<td>manageable</td>
<td>Radio and TV</td>
</tr>
<tr>
<td>22</td>
<td>1284</td>
<td>11.87</td>
<td>1 : 4.8</td>
<td>very difficult</td>
<td>Uptown Garage</td>
</tr>
</tbody>
</table>

From the measurement in Table 5.1.1, it has been determined that the 11.1° ramp is the steepest incline that a wheelchair user should attempt to ascend by oneself. The 11.1° ramp is the steepest incline where the wheelchair maintains stability and the user is physically able to propel oneself up the ramp. Any ramp steeper than 11.1° is unsafe because the wheelchair may tip over backwards resulting in injury or become exhausted before reaching the top of the ramp. If exhaustion occurs while on the ramp, the user may lose his/her grip and could potentially roll uncontrolled back down the ramp, resulting in injury.

The input forces associated with an 11.1° ramp are a reasonable limit for a wheelchair torque assisting device. The ADA approved wheelchair ramp has a grade of 1:12 (4.76°). A torque assisting device should be designed to make the 11.1° ramp feel like an ADA approved ramp.

5.2 Concept Generation

The following concepts were proposed by the group. They came primarily from the individual team members doing sketches of ideas to possibly satisfy the need area.

5.2.1 Gearing/Mechanical Advantage Concepts

The following concepts would not require motors, controllers, or batteries, which may be advantageous to keeping the weight and cost of the chair low.
Figure 5.2.1: Detail of Gearing for Two-Speed Wheelchair

This device would provide two geared settings in which the chair could operate: a one-to-one gearing ratio and another gearing ratio to provide higher torque to the wheels. In this device, the shifting mechanism would be sliding the hand wheel toward/away from the chair.
**Figure 5.2.2: Alternative Drive Mechanisms for Gearing**
This sketch shows the possibility of having a chain or belt mechanism that has a similar effect as the gearing in Figure 5.2.1. Here the shifting mechanism would likely be a bicycle style derailleur system.

**Figure 5.2.3: Ratchet Arm Device for Increasing Torque to Wheels**
This device would use a telescoping lever arm to decrease the force required to climb a steep ramp.
Figure 5.2.4: Planetary Gear Concept for Wheelchair Assist
This device shows a configuration of a planetary gearing system where the center sun gear would be attached to the hand wheel of the chair and the outer race would drive the wheels. There are idlers between the sun and planet gears to assure that the wheel turns in the same direction as the hand wheel.

Figure 5.2.5: Crank and Chain Concept
This figure shows a device that creates mechanical advantage using a crank that would be up around chest level on the wheelchair that is connected to a small drive gear. The size ratio between the little drive gear and the large gear on the wheel would create most of the advantage. The lever of the crank handle would affect the dynamics some as well.
This design uses a three-speed geared hub connected to an input handrail for torque conversion. The geared hub was originally designed for use in the back wheels of bicycles, but was modified to produce the desired gear ratios necessary for a wheelchair application.

5.2.2 Battery/Motor Concepts

The following concepts contain heavy components (batteries, motors, etc.) The possible benefits of such components are that they would enable the user to have an increased speed for a lower input force that is not possible with a mechanical system. One goal of all of these concepts would be to possibly regenerate battery power when the torque assist feature is not in use.
Figure 5.2.7: Electric Motor with Friction Drive to the Tire
This concept would use a motor in contact with the tire. When the torque assist is not in use, the motor might be used as a generator to recharge the battery.

Figure 5.2.8: Motor Drive to the Shaft of the Wheel
This concept would have an electric motor geared straight to the shaft of the wheel. Then, a second component, either a low resistance generator or alternator could switch to the gearing when the torque assist is not engaged to recapture some of the energy.
Figure 5.2.9: Stirling Engine(s) Used for Energy Regeneration
One or more Stirling engines would convert the body heat of the occupant into mechanical energy that could be used to run a generator to recharge the battery. One of the other electric motor concepts would supply the torque assist.

Figure 5.2.10: Air Pressure Driven Piston for Assist
This concept would use air pressure to add torque to the wheelchair. It is also possibly a regenerative system by switching the valve positions. Some additional device would be needed in recharge mode so that it would require less pressure to turn the wheels.
5.3 Initial Screening for Feasibility/Effectiveness

Initial screening asks to following questions:
1. Is the power input reasonably safe?
2. Is the technology sufficiently developed that it can be applied to this problem?
3. Is it reasonable to expect that a certain input can provide sufficient power to accomplish the goal?
4. Is the required input source reliable? (I.e. a wind device using sails is not feasible because wind is not a sufficiently reliable input.)
5. Does the device rely on heavy components to function?

The answer to 1-4 needs to be yes and the answer to 5 no before an in-depth analysis can be started on a concept idea.

Concepts that did not pass this initial screening include:
- Combustibles (safety)
- Wind Power (reliability)
- Fuel Cells (availability of technology)
- Steam (safety, weight)
- Weight Drives (weight)
- Grappling hooks (safety)
- Stirling (weight)

6.0 Concept Selection

6.1 Data and Calculations for Feasibility and Effectiveness Analysis

6.1.1 Feasibility for a mechanically geared wheelchair

To determine the feasibility of a mechanically geared wheelchair, the gear ratio needed to make the input force required to ascend a specified steep ramp the same as the input force required to ascend an ADA standard ramp must be calculated. The slope of an ADA standard ramp rises one foot in twelve feet of run, which is 4.8°. The specified steep ramp is 11.1°.

The input force required to keep a wheelchair stationary on an ADA standard ramp and the specified steeper ramp was calculated. The wheelchair was represented by a disk with the center of mass located at the center of the disk. It was assumed that wheels will never slip.
1) \[ \sum F_x = ma_x = 0 \Rightarrow W \times \sin(\theta) - P - F = m \times a_x = 0 \]

2) \[ \sum F_y = ma_y = 0 \Rightarrow N - W \times \cos(\theta) = m \times a_y = 0 \]

3) \[ \sum M = J\alpha = 0 \Rightarrow P \times r - F \times r = J\alpha = 0 \]

Since there is no motion: \( a_x = 0, a_y = 0, \alpha = 0 \)

4) \[ P \times r = F \times r \Rightarrow P = F \]

Combine 1) and 4)

5) \[ W \times \sin(\theta) = 2P \Rightarrow P = \frac{W \times \sin(\theta)}{2} \]

For the ADA ramp: \[ P = \frac{W \times \sin(4.7636)}{2} = W \times 0.0415 \text{ Pounds} \]

For the steep ramp: \[ P = \frac{W \times \sin(11.1)}{2} = W \times 0.0963 \text{ Pounds} \]

Gear ratio \[ \frac{0.0963}{0.0415} \Rightarrow 2.32:1 \]

Target Gear ratio = 2.32:1
A gear ratio of 2.32:1 is easily feasible.

This calculation only accounts for the static case of holding oneself in place on a ramp. More force than this will be required to accelerate a wheelchair up a ramp. Also, this calculation assumes a wheelchair to be a disk with lumped loading at the axle. This provides a good first approximation of the problem.
6.2 Concept Screening

The list of concepts must be evaluated for several important qualities to ensure that the correct solution is chosen that fulfills the needs statement. These qualities were determined in Section 2.0 during customer interviews and quantified in terms of specifications in Section 3.2.

6.2.1 Customer Feedback

A follow-up interview with Dr. Carolyn Lewis by e-mail allowed her to comment on the completeness and importance of the compiled customer needs list. Her responses are shown below:

- **Reliability of device when used** -- This is extremely important. If the device is not reliable, a person with disabilities will be unable to get to planned appointments, get up ramps, maneuver, and may get stuck in various situations.
- **Easy maintenance** -- Easy and inexpensive maintenance is critical. Easy to decipher maintenance instructions would be necessary.
- **Regenerative Braking to recharge battery** -- Excellent idea. This would solve the problem of having to recharge at an outlet that might not be readily available.
- **Aesthetics** -- This is not very important. Functionality and reliability are the two essential elements.
- **Weight of the device** -- A lightweight device is essential and a device that can be easily stored.
- **Safety features of the device** -- There should be no sharp or rough edges.
- **Recharge Time for battery** -- A short recharge time is important.
- **Range of travel** -- Important.
- **Maneuverability** -- Important.
- **Ramp/Grade Accessible** -- Essential.
- **Environmental Resistance** -- Important.
- **Learning period for user** -- Important.
- **Ergonomics** -- Essential.
- **Cost** -- Many persons with disabilities don't have high incomes and insurance companies don't often pay for items they deem as an "extra." The cost cannot be prohibitive.
- **Durability of device** -- Essential. The device should not only be durable, but have a warranty or a system for replacement parts.

6.2.2 Screening Process

The concepts that fully met the revised need statement were judged on a pros and cons basis that was concerned with meeting the customer needs, feasibility and conforming to current ANSI standards.
Table 6.2.1: Pros and Cons of a Mechanical vs. Electrical System

<table>
<thead>
<tr>
<th>Pros</th>
<th>Mechanical</th>
<th>Cons</th>
<th>Electrical</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lighter</td>
<td>Torque reduction will reduce speed</td>
<td>Can go faster with reduced effort</td>
<td>Batteries will add weight</td>
<td></td>
</tr>
<tr>
<td>Never needs to be charged</td>
<td>More moving parts means more things that can break</td>
<td>Batteries will need to be charged</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unique to the market</td>
<td>Person must generate all power</td>
<td>If batteries are dead, the system is useless</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mechanical design</td>
<td></td>
<td>More expensive</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Potential for electrical complexity</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Many similar products already exist</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

6.3 Concept Development, Scoring and Selection

Many concepts were considered during our initial work toward a solution. The main feasible ideas were mechanical gearing, electric assistance and air pressure. These resulting feasible ideas were reduced from a long list of brainstormed ideas due to their design difficulty being reasonable. The feasible ideas were then examined in a pros versus cons lists created by the group and set up into a decision matrix as shown in Table 6.3.1. These matrices use a simple 1-3 scale for both ranking and weighting with 3 being favorable and 1 being unfavorable. The ranking did not answer the question “how safe is it?” instead of “how easily can it be designed for safety?” and likewise for the other traits.

Table 6.3.1: Assistance Power Source Decision Matrix

<table>
<thead>
<tr>
<th>Assistance source</th>
<th>Safe</th>
<th>Cost</th>
<th>Feasible</th>
<th>Light-weight</th>
<th>Rage</th>
<th>Able to Retrofit</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weighting</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>36</td>
</tr>
<tr>
<td>Mechanical Gearing</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Electric Assist</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>21</td>
</tr>
<tr>
<td>Air pressure</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>15</td>
</tr>
</tbody>
</table>

Mechanical gearing was found to be the solution that most satisfied our team’s need statement and goals for the project. Then a second decision matrix was used to further refine the precise design of the mechanical gearing as shown in Table 6.3.2.
Table 6.3.2: Mechanical Input Type Decision Matrix

<table>
<thead>
<tr>
<th>Input source</th>
<th>How easy is it to achieve this?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Safe</td>
</tr>
<tr>
<td>Weighting</td>
<td>3</td>
</tr>
<tr>
<td>Crank</td>
<td>1</td>
</tr>
<tr>
<td>Ratchet/lever</td>
<td>1.5</td>
</tr>
<tr>
<td>Existing wheel hub</td>
<td>3</td>
</tr>
<tr>
<td>Secondary hub</td>
<td>2</td>
</tr>
</tbody>
</table>

Based on the team’s input into the decision matrices, the final concept was narrowed to a mechanical design where the input force is through the existing wheel hub. This concept allows for a design in which the torque input to the hand-wheel is multiplied through one of several choices: planetary gears, spur gears in a gearbox, chain/belt drives or three-speed geared hub. These four options were discussed and three of the options were eliminated for reasons as follows:

- Planetary gears- Too complex
- Spur gears in a gear box- Too design intensive
- Chain/belt drive- Chair must be in motion for shifting to take place. Also device it too large

The final choice (see Figures 6.3.1 and 6.3.2) of the three-speed gear hub provides many advantages. It has a high level of safety, ease of operation, ability to retrofit, ability to maneuver, and is lightweight. More time can be spent focusing on the user interface and configuration with the chair as opposed to designing gearing because the hub can be purchased commercially. It allows for three gear ratios. The gear shifting can be done while the chair is stationary or moving.

By customizing wheelchair wheels with commercial hubs, the wheelchair will be capable of varying levels of torque assist. A pre-fabricated gear hub provides the necessary gearing in a small, affordable package and redirects design efforts to mounting and compatibility issues. The gearing on a hub will be adjusted to reach the specified 2.32:1 ratio for climbing an 11.1° ramp. Initially a three-speed hub will be used, so the wheelchair will therefore have at least two other speeds: preferably, a direct drive and an intermediate torque reduction. With possession of the hub, it will be taken apart to determine how to change or modify the internal components to reach the desired gear ratio. Directions for such modifications already exist online. One disadvantage is that the hub is designed for a bicycle and therefore it cannot go backwards and must be modified. This modification is not beyond the team’s skills.

The low gear will increase the amount of time the hand-wheel will need to be rotated to move a certain distance, but it will decrease the necessary input torque to turn the drive wheels. The geared state would only be used for short periods of time and the operation would be identical to normal operation leading to nearly no learning time. Added benefits of this solution include, the possibility of a higher gear that would allow higher speed travel over flat ground; the
possibility of having several gears for varying grades and the possibility to attach disk brakes to
the hub to allow better stopping control.

Figure 6.3.1: System overview- Side view

Figure 6.3.2: System overview – front view

6.3.1 Final Concept Feasibility

Geared hubs are very easy to find because they are used in many bicycles. They are very
reasonably priced and will easily fit into the budget. Some other advantages are that geared hubs
are designed with various configurations of gearing that can fit the project’s needs. They are
easy to operate and modify and are built lightweight due to their applications. Several
companies, including Sturmey-Archer, Rohloff, and Shimano, sell these hubs in two through
fourteen-speed models.

If such modifications are deemed too complex, then additional external gearing to an
attached sprocket may be required to adjust the overall drive ratio. Gear hubs are available that
reach the required ratio, but hubs with more than three-speeds increase rapidly in cost to as much as $1200 a piece.

This design can also be achieved within the size, cost, and weight constraints. As shown in Table 6.3.3, the hub is compact, well below our 10 lb limit and inexpensive at a cost of around $100. Some available three-speed gear hubs are shown in Figures 6.3.3 – 6.3.5.

Table 6.3.3: Three-Speed Gear Hubs

<table>
<thead>
<tr>
<th>Model</th>
<th>Length (in)</th>
<th>Diameter (in)</th>
<th>Material</th>
<th>Finish</th>
<th>Weight (lbs)</th>
<th>Gear Ratios</th>
<th>Gear Range</th>
<th>Cost ($)</th>
<th>Shifter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sturmey Archer AW</td>
<td>6.89</td>
<td>2.56</td>
<td>SPCC Steel</td>
<td>Corrosion Resistant</td>
<td>2.33</td>
<td>1st .75</td>
<td>177%</td>
<td>$100-120</td>
<td>no</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2nd 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3rd 1.33</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shimano Nexus Inter-3</td>
<td>6.89</td>
<td>2.36</td>
<td>Steel</td>
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Figure 6.3.3: Sturmey Archer (Hubs)
Figure 6.3.4: Shimano Nexus Inter-3 (Products)

Figure 6.3.5: SRAM T3 (Parts)
References


Project Planning for Winter Break and First Week of Winter Quarter

Due to the obvious communication issues and time conflicts associated with winter break, Stocker Center Street Gang plans on only completing limited assignments during this period. An outline of tasks that we will work on during break is supplied below. All inter-team communication will take place with phone calls and emails.

Outline of Tasks to be completed during Winter Break

- Research and develop a method for modifying 3 speed bike hubs to desired gear ratios
- Create a chart of gearing ratios commercially available for 3 speed bike hubs
- Search for more customers who fit our needs area, specifically males, since all of our current customers are female
  - Give new customers the team’s questionnaire for feedback
- Procure more wheelchairs for use during winter quarter
- House clean our file exchange
- Enjoy break and come back refreshed to continue project

Outline of Tasks to be completed during first week of Winter Quarter

- Report and discuss finding of winter quarter tasks as a group (findings will be discussed during winter break, but this will be our first opportunity to meet in person and clarify any misunderstandings due to lack of good communication during break)
- Update necessary changes to our Design Report
- Prepare for Preliminary Design Leadership Team Review #1 which occurs on the second week.
- Create a budget