Powered Wheelbarrow

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by

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ABSTRACT
The wheelbarrow is an effective and timeless tool that helps people transport heavy loads. The one drawback to the wheelbarrow, however, is that it lacks any type of automation to help the operator. The Powered Wheelbarrow aims to add automation to the wheelbarrow in order to help people conserve their energy while using it.

Extensive research found various existing products such as the Jackson wheelbarrow, the Gorilla Cart and the Lifetime brand wheelbarrows, but all of these products still lacked the automated performance proposed by the Powered Wheelbarrow. One existing product, the Power Buggy, did have a motor on it, but at a price of nearly $10,000, it is marketed more for businesses and not the everyday homeowner/handyman.

Customer input was collected and analyzed which led to the most important characteristics being durability, ease of unloading and maneuverability. From here, it was also determined that in order to meet these customer requirements, the power of the motor, the overall weight and the material selected would be key characteristics to focus on.

The design phase started by weighing different options in order to find the best motor to drive the wheelbarrow and the best way to dump the load without human power. It was ultimately decided that the motor from an IZIP i500 electric scooter would be best for the drive motor and a Black Bull electric car jack would be the best alternative to dump the load. Next, a support was designed to hold the jack and two other frames were designed to allow the bucket to pivot above the tire and dump the load without lifting the frame; like a dump truck.

Once the design work was completed and all of the necessary material was acquired, fabrication and assembly took place. Operations such as metal cutting with a band saw, grinding, TIG welding, and nut and bolt assembly all led to the successful creation of the final Powered Wheelbarrow assembly. All the pieces were then painted in Rustoleum paint in order to help protect everything from the elements.

Through testing, the Powered Wheelbarrow proved to meet the goals set out. It successfully carried a 210lb load across flat ground, up a 30° incline and through a basement being remodeled. Additionally, the jack was able to achieve its maximum height with the 210lb load and it was simple to dump the load the rest of the way.

The Powered Wheelbarrow maintains its ability to perform like all other wheelbarrows while also being able to lighten the burden on the operator. Multiple trips, uphill treks and tight turns are now easier to perform with the Powered Wheelbarrow. The energy saved by the Powered Wheelbarrow can now be put into the task at hand.
INTRODUCTION
The wheelbarrow is an effective tool that has been used for centuries to help move large loads of material around. The drawback to the standard wheelbarrow, however, is that its operation relies solely on the strength of the operator. Developing a product which assists the operator in both maneuvering and dumping would allow for more people to utilize the wheelbarrow for everyday tasks.

RESEARCH
Research was conducted through the examination of existing products along with data collection through interviews and a customer survey. Appendix A includes the raw research data as well as interview notes.

On September 8, 2012, a thread was started on www.300zxclub.com. This forum caters to enthusiasts of the Nissan Z series car. However, many of these car owners are engineers and handy men themselves. A question was posed about what would be desired in an updated wheelbarrow. Upon evaluating the responses, the general consensus showed that there was a desire for some sort of dump assistance and some type of drive assistance. Many of the responders had used a wheelbarrow and are tired of how much energy it takes to use. (1)

On September 13, 2012, an interview was conducted with Tom Wagner. Tom, who has been in the construction field for over thirty years and is a handyman himself, pointed out areas of improvement to be, “motorized to assist with hills, self leveling bucket for hills, more comfortable handles and a dumping assist.” (2)

EXISTING WHEELBARROW DESIGNS
The wheelbarrow is a very old design that, over the years, has produced many different iterations. One example of a typical wheelbarrow is the Jackson medium duty wheelbarrow, pictured in Figure 1. (3)

![Figure 1 Jackson Wheelbarrow](image)

Figure 1 Jackson Wheelbarrow

The Jackson medium duty wheelbarrow utilizes the most common one wheel with two support legs design. This is a great accessory for any type of worker, whether it be a do it yourself homeowner or a construction worker. The rugged steel bucket and frame are
designed to last for years. However, this design still requires a significant amount of energy to be exerted by the operator when moving and dumping material. With no motorized components, the operator is the sole input required to move the loads that this wheelbarrow is capable of hauling.

A different approach to the wheelbarrow design can be seen in the Gorilla Cart heavy duty dump cart, pictured in Figure 2. (4)

![Figure 2 Gorilla Carts Heavy Duty Dump Cart](Image)

The Gorilla Cart utilizes a four wheel, wagon design. This design gears more towards homeowners who would use this cart to haul mulch and flower around their yard. With four wheels, it is not as maneuverable as the Jackson design, but it does have a dump gate which allows for easier unloading. However, the single handle is not ideal for pulling around heavy loads and the plastic bucket could prove brittle under continuous strikes with a spade shovel.

Designed for larger jobs and not very practical for the average homeowner, is the Power Buggy, pictured in Figure 3. (5)

![Figure 3 Power Buggy](Image)

The Power Buggy is a rugged machine designed for larger construction jobs. It utilizes an engine to carry approximately 3,000 pound loads up to 7MPH. Additionally, the Power Buggy has a dumping system to allow the bucket to easily tip and allow for removal of the load. However, at around $9,000, this buggy is a huge investment that most standard do it yourselfers cannot afford to make.
Developed around a two wheel cart design, the Lifetime wheelbarrow is designed for smaller jobs, such as gardening, and is pictured in Figure 4. (6)

![Figure 4 Lifetime Wheelbarrow](image)

The two wheel design of the Lifetime wheelbarrow allows for great maneuverability and its pivot point allows for easy dumping of the load. However, its plastic bucket could break under repeated hits of a shovel and its back support bar would make it hard to push uphill as the bar would dig into the ground. It is a good alternative for small jobs like transporting flowers and light loads of mulch, but it is not intended for heavier loads or applications such as concrete.

Lifetime also makes another two wheeled wheelbarrow, but this one follows a cart design more. The Lifetime 2-Way dumping wheelbarrow, seen in Figure 5, is a step above the Lifetime wheelbarrow. (7)

![Figure 5 Lifetime 2-Way Dumping Wheelbarrow](image)

The 2-way dumping wheelbarrow also utilizes a two wheel cart design, but it has two angled handles instead of straight handles. Additionally, the handles can drop down and reveal a tow hitch to pull the wheelbarrow with a tractor. The 2-way also allows the bucket to dump making it easier for the operator to remove the load. However, the way this is designed with two wheels and a long bucket makes for harder maneuverability in tight places. Also the handles are closer than normal wheelbarrows which could make it harder to push or pull heavy loads with such a close grip.
The last product researched was the Narrow Barrow wheelbarrow, pictured in Figure 6. (8)

![Narrow Barrow Wheelbarrow](image)

Figure 6 Narrow Barrow Wheelbarrow

The Narrow Barrow wheelbarrow does not claim to be suited for hauling the biggest loads or working with materials such as concrete, but it is best suited for gardening. Its greatest feature is its cloth bucket, allowing it to fold up for storage. It remains the same as a standard wheelbarrow where the user supplies all the force for maneuvering and dumping, but it separates itself by being able to take up virtually no room when stored.

The research conducted looked at all variations of a wheelbarrow that could be found. After completing the research, a customer survey was created and sent out in order to see what exactly the customers wanted in a new, powered wheelbarrow.
CUSTOMER FEEDBACK
A survey was created and then sent out to small time construction workers and everyday people who have used a wheelbarrow; the intended customer. Ten completed surveys were returned. This survey asked the customer to rank ten product objectives on a scale of 1-5 in order to determine how important each feature was to the customer. Additionally, the survey asked the customers to rank their satisfaction with respect to each design feature on their current wheelbarrow. The full results of the ten completed surveys can be seen in Appendix B.

SURVEY ANALYSIS
The results of the survey can be seen in Table 1. This information was imperative in that it shows what objectives are most important to the customer and this ultimately steers the design phases to meet the most important objectives. The survey results were clear in indicating that the two most important objectives were durability and maneuverability.

Table 1 Customer Importance Survey Results

<table>
<thead>
<tr>
<th>Product Objectives</th>
<th>Average Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Durability</td>
<td>4.5</td>
</tr>
<tr>
<td>Maneuverability</td>
<td>4.3</td>
</tr>
<tr>
<td>Safety</td>
<td>4.0</td>
</tr>
<tr>
<td>Low Maintenance</td>
<td>4.0</td>
</tr>
<tr>
<td>Ease of Operation</td>
<td>4.0</td>
</tr>
<tr>
<td>Capacity</td>
<td>3.9</td>
</tr>
<tr>
<td>Cost</td>
<td>3.7</td>
</tr>
<tr>
<td>Ease of Unloading</td>
<td>3.7</td>
</tr>
<tr>
<td>Comfort</td>
<td>3.0</td>
</tr>
<tr>
<td>Ease of Cleaning</td>
<td>2.6</td>
</tr>
</tbody>
</table>
Additionally, upon obtaining the most important features of the customers, their current satisfaction was examined with the use of the second half of the survey. A QFD, or Quality Function Deployment, was created to organize the customers’ current satisfaction with their wheelbarrow, the planned satisfaction from a new product, the modified importance of the objective and the relative weight of the objective. Table 2 shows the results from the surveys as well as the new relative weight of each objective.

**Table 2 Customer Importance, Planned Satisfaction, Relative Weight**

<table>
<thead>
<tr>
<th>Objectives</th>
<th>Current Satisfaction</th>
<th>Planned Satisfaction</th>
<th>Improvement Ratio</th>
<th>Modified Importance</th>
<th>Relative Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Durability</td>
<td>4.1</td>
<td>5</td>
<td>1.2</td>
<td>5.5</td>
<td>13%</td>
</tr>
<tr>
<td>Ease of Unloading</td>
<td>3.4</td>
<td>5</td>
<td>1.5</td>
<td>5.4</td>
<td>13%</td>
</tr>
<tr>
<td>Maneuverability</td>
<td>3.9</td>
<td>4</td>
<td>1.0</td>
<td>4.4</td>
<td>11%</td>
</tr>
<tr>
<td>Capacity</td>
<td>3.6</td>
<td>4</td>
<td>1.1</td>
<td>4.3</td>
<td>10%</td>
</tr>
<tr>
<td>Safety</td>
<td>3.7</td>
<td>4</td>
<td>1.1</td>
<td>4.3</td>
<td>10%</td>
</tr>
<tr>
<td>Low Maintenance</td>
<td>4.7</td>
<td>5</td>
<td>1.1</td>
<td>4.3</td>
<td>10%</td>
</tr>
<tr>
<td>Cost</td>
<td>3.6</td>
<td>4</td>
<td>1.1</td>
<td>4.1</td>
<td>10%</td>
</tr>
<tr>
<td>Ease of Operation</td>
<td>4.3</td>
<td>4</td>
<td>0.9</td>
<td>3.7</td>
<td>9%</td>
</tr>
<tr>
<td>Comfort</td>
<td>2.8</td>
<td>3</td>
<td>1.1</td>
<td>3.2</td>
<td>8%</td>
</tr>
<tr>
<td>Ease of Cleaning</td>
<td>4.6</td>
<td>4</td>
<td>0.9</td>
<td>2.3</td>
<td>5%</td>
</tr>
</tbody>
</table>

The average results from the second half of the survey were compiled and can be seen in Table 2 under “Current Satisfaction”. From the table, it can be seen that customers were least satisfied with the comfort and ease of unloading of their current wheelbarrow. Next, the “Planned Satisfaction” shows if the designer expects to raise or lower the current satisfaction scores. The most drastic change here was to the ease of unloading. It was determined that the powered wheelbarrow was going to help automate the unloading action and ultimately make it easier. Continuing, the “Improvement Ratio” is a direct result of how much the current satisfaction raises or lowers in order to meet the planned satisfaction. The “Modified Importance” looks at the values in Table 1 and multiplies them to the “Improvement Ratio” to obtain an adjusted importance based on satisfaction. Finally, the “Relative Weight” is obtained to show which objectives are most important to satisfy the customers’ needs. From the data, it is clear that durability and ease of unloading are the main focus of the design.

Upon obtaining relative weights, the objectives of the design were modified to show the importance of each objective.
PRODUCT FEATURES AND OBJECTIVES

The product objectives come straight from the customer requirements that were used in the survey. The objectives aim to show ways in which the feature will be met to fulfill the customer needs. Each objective will have to have some sort of measurable or observable feature in order to test the final design to see whether or not the objective was met. These objectives are organized by the relative importance weight that was determined through the QFD and can be seen in Table 2.

OBJECTIVES

1) Durability (13%)
   a) Design factor consistent with loading conditions and expected use
   b) Rust-resistant material selection or coated with weather resistant coating
   c) Mudguards
   d) Metal bucket for best impact resistance with tools (shovels, etc)

2) Ease of Unloading (13%)
   a) Dumping assistance
      i) Designed to dump load without tipping the wheelbarrow itself

3) Maneuverability (11%)
   a) Motor assists, when needed, with maneuvering heavy loads
   b) Able to turn 360° without moving forward or backward
   c) Can fit through standard 30” doorway

4) Safety (10%)
   a) Dead man switch for throttle
   b) Hand brake to control speed going downhill, sized to grade and weight
   c) Guards or signs for all moving parts
   d) Guards or signs for all pinch points

5) Cost (10%)
   a) Final prototype cost is less than $1,000

6) Low Maintenance (10%)
   a) No oil change on motor
   b) No lubrication of bearings

7) Capacity (10%)
   a) Minimum of 5 cubic foot capacity
   b) Capable of hauling 200lbs

8) Ease of Operation (9%)
   a) Controls will be standard types
      i) Grip handle, ON/OFF switch, push button
   b) Controls are within normal range of human operation according to human factors for normally functioning adult

9) Comfort (8%)
   a) Consistent with commercial wheelbarrow comfort
   b) Controls will be standard comfort

10) Ease of Cleaning (5%)
    a) Water proof materials
    b) Motor and drive system protected from debris (both from cleaning and from carrying a load)
c) Drive components above axle  
d) Motor is either covered or removable for cleaning

The QFD was also utilized to figure out the top engineering characteristics. As seen in Table 3, the top three characteristics are the power of the motor, the weight and material selection. These three areas will be key decisions in order to successfully meet the product objectives.

Table 3 Engineering Characteristics

<table>
<thead>
<tr>
<th>Engineering Characteristic</th>
<th>Relative Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power of Motor</td>
<td>25%</td>
</tr>
<tr>
<td>Weight</td>
<td>15%</td>
</tr>
<tr>
<td>Material Selection</td>
<td>14%</td>
</tr>
<tr>
<td>Bucket Size</td>
<td>13%</td>
</tr>
<tr>
<td>Standard Components</td>
<td>12%</td>
</tr>
<tr>
<td>Width</td>
<td>10%</td>
</tr>
<tr>
<td>Paint</td>
<td>7%</td>
</tr>
<tr>
<td>Height</td>
<td>5%</td>
</tr>
</tbody>
</table>

Now that the objectives have been explained and it is known what the design intends to achieve, the design steps for this project will be clarified.
CONCEPT DESIGN

**DRIVE SYSTEM**

When powering the drive system, two different types of motors were looked at: a drill and an electric motor from a riding scooter. The results of the weighted rating method used to decide which motor would be the best alternative can be seen in Table 4, below. Using the criteria and importance weight from the QFD, each motor was ranked on a scale of 0-4, with 4 being the best. Both motors proved to be equal in almost every category except durability. It was determined that since the scooter motor was encased in metal and better protected from water and debris than the drill, it would ultimately prove to be a more durable option. Additionally, the cost of the scooter motor proved to be cheaper than the necessary high torque drill. Finally, after multiplying the weights with the rating and summing the results, the electric scooter motor ended up being the best way to automate the drive system.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Importance Weight (%)</th>
<th>Drill Motor</th>
<th>Electric Scooter Motor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rating</td>
<td>Weighted Rank</td>
<td>Rating</td>
</tr>
<tr>
<td>Durability</td>
<td>0.13</td>
<td>3</td>
<td>0.39</td>
</tr>
<tr>
<td>Ease of Unloading</td>
<td>0.13</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Maneuverability</td>
<td>0.11</td>
<td>3</td>
<td>0.33</td>
</tr>
<tr>
<td>Safety</td>
<td>0.1</td>
<td>4</td>
<td>0.4</td>
</tr>
<tr>
<td>Cost</td>
<td>0.1</td>
<td>2</td>
<td>0.2</td>
</tr>
<tr>
<td>Low Maintenance</td>
<td>0.1</td>
<td>3</td>
<td>0.3</td>
</tr>
<tr>
<td>Capacity</td>
<td>0.1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Ease of Operation</td>
<td>0.09</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Comfort</td>
<td>0.08</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Ease of Cleaning</td>
<td>0.05</td>
<td>3</td>
<td>0.15</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>0.99</strong></td>
<td><strong>1.77</strong></td>
<td><strong>2.05</strong></td>
</tr>
</tbody>
</table>
The selected motor came from the IZIP i500 Electric Scooter, pictured in Figure 7 (9). This 24V, 500W motor was chosen based on availability and capability. Including the weight of the scooter, which will be removed for the wheelbarrow, this motor is rated with a maximum capacity of 300lbs. This rating is greater than the weight of 250lbs which includes both the wheelbarrows weight and max load. Additionally, the motor can reach speeds of up to 15mph and comes with a rechargeable battery that is good for up to 8 miles per charge, depending on the load.

Figure 7 IZIP i500 Electric Scooter

Now that the selection of the motor was described, the design of the lift system will be explained.
LIFT SYSTEM

When it came to lifting the bucket to remove part of the load without operator assistance, three alternatives were looked at: a compression spring, a torsion spring and a scissor jack (the emergency jack found in cars). The weighted rating method used to find the best lifting method can be seen in Table 5.

Table 5 Weighted Rating Method - Lift System

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Importance Weight</th>
<th>Torsion Spring</th>
<th>Compression Spring</th>
<th>Scissor Jack</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rating</td>
<td>Weighted Rank</td>
<td>Rating</td>
<td>Weighted Rank</td>
</tr>
<tr>
<td>Durability</td>
<td>0.13</td>
<td>3</td>
<td>0.39</td>
<td>3</td>
</tr>
<tr>
<td>Ease of Unloading</td>
<td>0.13</td>
<td>3</td>
<td>0.39</td>
<td>3</td>
</tr>
<tr>
<td>Maneuverability</td>
<td>0.11</td>
<td>2</td>
<td>0.22</td>
<td>2</td>
</tr>
<tr>
<td>Safety</td>
<td>0.1</td>
<td>2</td>
<td>0.2</td>
<td>2</td>
</tr>
<tr>
<td>Cost</td>
<td>0.1</td>
<td>3</td>
<td>0.3</td>
<td>3</td>
</tr>
<tr>
<td>Low Maintenance</td>
<td>0.1</td>
<td>3</td>
<td>0.3</td>
<td>3</td>
</tr>
<tr>
<td>Capacity</td>
<td>0.1</td>
<td>2</td>
<td>0.2</td>
<td>2</td>
</tr>
<tr>
<td>Ease of Operation</td>
<td>0.09</td>
<td>2</td>
<td>0.18</td>
<td>2</td>
</tr>
<tr>
<td>Comfort</td>
<td>0.08</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Ease of Cleaning</td>
<td>0.05</td>
<td>3</td>
<td>0.15</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>0.99</td>
<td>2.33</td>
<td>2.33</td>
<td>2.08</td>
</tr>
</tbody>
</table>

It can be seen that the torsion and compression springs are the better alternative; however, calculations proved that a compression spring capable of lifting the load would not have a long enough stroke length and a torsion spring would be too large for the wheelbarrow. Therefore, going with a scissor jack, the Black Bull Electric Car Jack was selected to raise the load and can be seen in Figure 8 (10). This jack runs off of a 12V battery supply and can lift 1 ton to a height of 9 inches. Having this electric jack will remove the operators need to lift the load for this first 9 inches.

Figure 8 Black Bull Electric Car Jack
The jack will be positioned in between the handle bars and supported by a rectangular pipe as shown in Figure 9 below. The calculations used to determine the size of the pipe needed can be seen in Figure 10, with the full work located in Appendix F. First, a basic free body diagram was set up with two supports at each end and the 250lb load (200lb load and 50lb bucket) in the center. Determining the resulting forces allowed for the shearing force and bending moment diagrams to be generated to find the maximum bending moment. From this, it is known that about a three inch lift will be needed, therefore, a 2.5inch x 1.5inch x 1/8inch pipe was chosen since the jack itself will provide the three inch lift. Next, the design stress was found using the maximum bending moment, C (the perpendicular distance to the neutral axis, and I (the moment of inertia about the neutral axis). With this design stress, the factor of safety was found using the yield strength of steel of 36ksi. Calculations determined a factor of safety of 16 which means that this setup is more than enough to support the loading.

Figure 9 Jack Support

\[
M = 125lb \times 7\text{in} = 875\text{inlb}
\]

\[
C = \frac{1.5\text{in}}{2} = 0.75\text{in}
\]

\[
I = 0.299\text{in}^4
\]

\[
\sigma_{\max} = \frac{875\text{inlb} \times 0.75\text{in}}{0.299\text{in}^4} = 2195\text{psi}
\]

\[
N = \frac{36\text{ksi}}{2.19\text{ksi}} = 16
\]

Figure 10 Jack Support Calculations
FRONT LIFT SYSTEM

In order to make the bucket dump without lifting the entire wheelbarrow frame, the bucket needed to be raised to allow it to clear the front wheel when rotating. A rotational support bracket was designed to lift the front end of the bucket above the wheel. This lift bracket will connect to the frame of the wheelbarrow at one end and the underside of the bucket at the other end. This positioning will allow the bucket to dump independently from the rest of the wheelbarrow and can be seen in Figure 11.

The calculations used to determine the forces acting on the rotation bracket with a full 250lb load can be seen in Figure 12, with the full work located in Appendix F. First, a free body diagram was created to show the forces acting on the axle with a 250lb load coming straight down and the two support beams supporting this load. A shifted coordinate system was then used to find the reaction forces, F1 and F2. Next, the max force of F2 was taken and the stress in the bar was found using the bars area. A stress of 3.742ksi was found. This stress is far below the yield strength of 36ksi so this design will work.

\[
A = 0.125 \text{in} \times 0.5 \text{in} = 0.0625 \text{in}^2
\]
\[
F_1 = 17.71 \text{lb}
\]
\[
F_2 = 234 \text{lb}
\]
\[
\sigma = \frac{234 \text{lb}}{0.0625 \text{in}^2} = 3.742 \text{ksi}
\]

Figure 11 Front Lift Bracket Assembly

Figure 12 Front Lift Support Calculations
ASSEMBLY MODEL

The full Solidworks model of the powered wheelbarrow can be seen in Figure 13.

Figure 13 Assembly Model

Now that the design portion of this project has been justified, the fabrication and assembly of the Powered Wheelbarrow will be detailed.
FABRICATION AND ASSEMBLY

DRIVE SYSTEM

After obtaining the necessary parts and materials, the first step in assembly was connecting the scooter motor to the wheel of the wheelbarrow. Due to the wheel being an unweldable material, Loctite Epoxy was used to mount the sprocket to the wheel. The motor was then aligned with the sprocket and chain and holes were drilled in the wheelbarrow frame to allow for a five inch diameter U-bolt to hold the motor down. The alignment of the chain and sprocket can be seen in Figure 14 below.

Two bolt holes were then drilled below the motor to allow bolts to go through the frame and push up against the motor. These bolts allow the operator to remove the motor easily and also allows for adjustability in chain tension. The bolts can be seen in Figure 15 below.

![Figure 14 Chain and Sprocket Alignment](image)

![Figure 15 Adjustable Motor Bolts](image)
After setting the motor, the batter pack was then set up along the plate that connects the two legs, the ON/OFF switch and charge port were moved to the wheelbarrow handle and the throttle was spliced into the wheelbarrow handle. Each of these results can be seen in Figures 16, 17 and 18, respectively.

Figure 16 Battery Location

Figure 17 ON/OFF Switch and Charge Port

Figure 18 Throttle Placement
LIFT SYSTEM

Fabrication of the lift system began with creating the jack support. Cutting the rectangular tube to the correct size was completed using a band saw. The tubing was then clamped into place and TIG welded in between the two handles. The support can be seen welded into place in Figure 19.

![Figure 19 Jack Support](image)

The jack was then centered onto the support and mounted using two bolts. The bolts allow for easy removal of the jack for cleaning or replacement. The mounted jack is shown in Figure 20 below.

![Figure 20 Mounted Jack](image)
Since the jack runs off of a 12 volt battery using a 12V vehicle adapter plug, a “12volt battery to lighter socket extension cord” was purchased. This purchased part can be seen in Figure 21.

A battery pack was then created using two 6 volt batteries wired together. Wire clamps were also attached to the wheelbarrow frame to allow the remote to hang secured when not being used. The final assembly of everything can be seen in Figure 22 below.
FRONT LIFT SYSTEM

Fabrication of the front lift system began by cutting tubing using a band saw. Next, the support legs were cut out of 1/8 inch thick sheet metal using a plasma cutter. The pieces were then assembled and TIG welded into place. The results of these processes can be seen in Figure 23.

Next, the axle was cut from a 5/8 inch diameter steel rod. Two, electrical, two-hole straps were then bolted onto the bucket to allow the axle to slide through and connect the frame to the bucket to allow for rotation. The assembly can be seen in Figure 24.
PVC piping was then cut and placed on the axel, in between the front lift frame and the two-hole straps in order to keep the bucket from sliding across the axle. Additionally, two holes were drilled through both sides of the axle to allow for cotter pins to be put in. The cotter pins keep the axle from sliding out during operation and also allow the user to remove them and the axle in order to break down the wheelbarrow for storage.

A handle was also bolted onto the backside of the bucket to allow for easier gripping when dumping the wheelbarrow the rest of the distance that the jack could not cover. The handle can be seen in Figure 25.

![Figure 25 Handle](image-url)
FRONT STOP

The front stop was added to ensure that the wheelbarrow would not tip over while dumping, and it also allows for easy cleaning of the bucket. First, small diameter ceiling wire was used to make a mock up of the actual rod shape. The actual stop was then made by bending a ¼ inch steel rod and TIG welding it to the wheelbarrow frame. The stop was placed so that the bucket would be able to rest on it and stand straight up with no help from the operator. The stop bar itself can be seen in Figure 26 and the final position of the bucket can be seen in Figure 27.

Figure 26 Front Stop

Figure 27 Front Stop Position

Now that fabrication and assembly has been detailed, the testing of the Powered Wheelbarrow will be outlined.
TESTING
The wheelbarrow was designed to carry a 200 pound load, so a 210 pound load of sand was put into the bucket. The load was then transported across a flat yard for approximately fifteen yards and then up a 30 degree inclined grass hill for approximately fifteen more yards. The entire time that the wheelbarrow moved, it was only under the power of the motor. The testers’ only responsibility was to lift the back legs off of the ground to allow the motor to drive the load.

Next, in order to test the dumping system, the 210 pound load was lifted solely by the jack to its maximum height. The tester then stood on the side of the bucket and used the handle and one hand to dump the load entirely. The load dumped with no tipping or any other issues. Additionally, the stop bar succeeded in keeping the bucket from flipping the wheelbarrow and allowed for a great position to clean out the bucket.

Finally, in order to test its maneuverability, the wheelbarrow was used to carry the 210 pound load around the basement of a house being remodeled. It was able to fit through the doors and make it through all of the tight corners easily with the help of the motor.

Now that the testing methods have been explained, the budget for this project will be explained.
BUDGET
The proposed budget was $307 more than the actual budget. The main area that saved money was being able to buy a used scooter motor as opposed to a new one. The entire budget can be seen in Table 6, below.

Table 6 Budget

<table>
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<tr>
<th>Component</th>
<th>Forecasted Amount</th>
<th>Actual Amount</th>
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<td>Motor</td>
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<td>$135.00</td>
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<tr>
<td>Wheelbarrow</td>
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<tr>
<td>Dumping Assembly</td>
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<td>Metal</td>
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<td><strong>Total</strong></td>
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<td><strong>$418.00</strong></td>
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</table>

Now that it is known what was budgeted for this project, the schedule of events will be addressed.
SCHEDULE
A simplified timeline of events for the project can be seen in Table 7. The grey blocks represent the proposed timeline whereas the red blocks represent the actual timeline.

Table 7 Schedule

<table>
<thead>
<tr>
<th></th>
<th>October</th>
<th>November</th>
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<tr>
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</table>

It can be seen that the project fell slightly behind schedule during the fabrication and assembly phase, but it ultimately got back on track in order to finish testing on time.

A full, detailed, schedule can be seen in Appendix E.
WORKS CITED
APPENDIX A - RESEARCH

Posted to online forum, http://www.300zxclub.com, on September 8, 2012. This forum caters to enthusiasts of the Nissan Z series car. Many of the members are handymen who like to do things themselves. A lot of engineers and other professional also frequent the site. A lot of interest has shown up for a better concept. Consensus showed that there should be a redesign of the way that you dump the load out of the wheelbarrow. Also, easier maneuverability is a big concentration area.

Brakes: Interest has been expressed about the addition of a braking system for controlling the load while going downhill.

Mechanical assist: Many would also like to see some sort of assist function either with the dumping or with moving, thus, decreasing the work done by the operator.

Interview with handy man and former construction company owner, Tom Wagner: 2590 Gallia Drive, Cincinnati, Ohio. 9/13/2012.

Tom has been working in construction for 30+ years. He owned his own construction business for seven years.

Possible areas of innovation with wheelbarrow: motorized to assist with hills, self leveling bucket for hills, more comfortable handles, dumping assist.

He liked my idea to work with the wheelbarrow and felt that one of the wheelbarrows biggest flaws was how it performs on hills. He has a rather large hill at his own property and while doing a lot of work around his house, he has to deal with this issue. Having a motor to assist the user up the hill would make work a lot easier. Also, if there was a way to level the bucket, transporting liquids downhill would lead to a lot less spillage.
### Jackson Steel Medium Duty Wheelbarrow

The Jackson steel medium duty wheelbarrow is geared toward homeowners, landscapers, and light construction work. It houses six cubic feet in its seamless steel tray that offers years of service.

The Jackson wheelbarrow includes:
- 6 cubic foot capacity
- Seamless steel tray
- 1-16 inch tubed knobby tire
- 60 inch seal coated hardwood handles

Width: 25.5 inches  
Length: 62.75 inches  
Height: 26.75 inches

Does not utilize true potential for storage capacity.  
The bar in front of the tire hits the ground when used by taller individuals.  
Has no assistance for user. The only power is provided by the user.

$99.99 USD

[Figure 28](http://www.jacksonprofessional.com/products/detail.aspx?ProductId=1088&SubFamilyId=270&FamilyId=269&LineId=34)

### Gorilla Carts Heavy Duty Dump Cart

Tricam Industries Gorilla Carts offers different sizes and weight capacities for users from lightweight homeowners to commercial-duty professionals. Their four wheel design eliminated the stabilization problems of the traditional single wheeled design. They also utilize a single pulling handle for maneuvering. The bed dumps to allow for easier removal of the load.

Gorilla Carts includes:
- 600lb-1,200lb capacity  
- Maintenance free poly bed  
- Powder coated steel frame  
- Tires: 4-15 inch pneumatic

Width: 32.5 inches  
Length: 49 inches  
Height: 28 inches

Four wheel designs make it more difficult to maneuver around tight areas.  
Single handle can prove difficult to hold transporting heavy loads up and down inclines.  
Height of the handle can cause taller users to hunch over to pull load.  
Plastic tubs are not ideal for work with concrete.  
Shovels and hoes can chip the plastic easily

$100-$150 USD

[Figure 2](http://tricamindustries.com/products/lawn-and-garden-carts/gorilla-carts/)

---

Appendix A2
The Power Buggy
The Power Buggy is a motorized wheelbarrow which allows the user to stand on a platform and drive their load around the area. It utilizes a rear wheel steering design to give it greater stability while still allowing it to turn easily. It is designed for more professional circumstances, can carry loads up to 7MPH and has a dumping system for the bed. The Power Buggy also has the option of a single set of front tires or a dual set. The dual set allows for a greater carrying capacity.

Figure 3

The Power Buggy includes:
- 2,500lbs-3,200lbs capacity
- Plastic bucket
- Tires: 5.7x8x19
- Operating weight: 1,260lbs-1,425lbs
Width: 43 inches
Length: 103 inches
Height: 35.5 inches(single tires) – 47 inches(dual tires)

http://www.thepowerbuggy.com/ 09/11/12

Its size and ability is not ideal for the everyday homeowner. The owner’s manual states that it cannot be used for going up an incline of more than 6° fore and aft of side to side. Plastic tubs are not ideal for work with concrete. Shovels and hoes can chip the plastic easily. Requires a lot of maintenance in regards to oil changes and general lubrication.

$9,000-$9,500 USD
Renting varies by location and duration.
The Lifetime Wheelbarrow
The Lifetime wheelbarrow is a two wheel design that aims attract smaller home projects, such as gardening. The 6.5 cubic foot tub is made from 100% post consumer recycled material and wider wheel base design boasts an 85% reduction in load. This design also utilizes stake pockets which allow the sides to be built up to accommodate tall loads.

The design of the handles makes it awkward to push uphill. Plastic tubs are not ideal for work with concrete. Shovels and hoes can chip the plastic easily. Taller users will find that they kick the bucket as they try to operate the wheelbarrow normally.

Figure 3
The Lifetime Wheelbarrow includes:
- 550lbs capacity
- High-density polyethylene plastic bucket
- Powder coated steel frame
- Tires: 2-15.5inch pneumatic

Width: 28 inches
Length: 58 inches
Height: 26 inches

$180 USD

**The Lifetime 2-Way Dumping Wheelbarrow**

The Lifetime 2-way wheelbarrow is a two wheel design that is geared towards more rugged work than the Lifetime Wheelbarrow. The tub is still made of 100% post consumer recycled materials and is housed on top of a powder coated steel frame. The handles provide a drop down feature which allows the wheelbarrow to hitch to a riding mower for easier transportation. This design also utilizes a dumping mechanism so the user does not have to lift the actual wheelbarrow to empty the load.

![Image](http://www.buylifetime.com/Products/BLT/PID-65009.aspx 09/11/12)

<table>
<thead>
<tr>
<th>Figure 3</th>
</tr>
</thead>
</table>

The Lifetime Wheelbarrow includes:
- 650lbs capacity
- High-density polyethylene plastic bucket
- Powder coated steel frame
- Tires: 2-15inch pneumatic

<table>
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<th>Width: 39 inches</th>
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</thead>
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<tr>
<td>Length: 67 inches</td>
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<tr>
<td>Height: 30 inches</td>
</tr>
</tbody>
</table>

The close grip of the handles makes it awkward to push or pull. Plastic tubs are not ideal for work with concrete. Shovels and hoes can chip the plastic easily. Taller users will find that they kick the bucket as they try to operate the wheelbarrow normally.

$275 USD
The Narrow Barrow Wheelbarrow
The Narrow Barrow wheelbarrow is a traditional three point design that is geared towards everyday gardening and yard work. The tub is made from a polyester fabric which allows it to collapse down to nine inches wide for easy storage. Additionally, the bag is replaceable so you do not need to buy an entire new wheelbarrow if the bag were to fail. Narrow Barrow also has hardware hangers and bag on the tub in order to add more room for tools.

The Narrow Barrow Wheelbarrow includes:
- 250lbs capacity
- Polyester fabric bed
- Powder coated steel frame
- Tire: 1-12inch polypropylene

Width: 32.5 inches (open), 9 inches (closed)
Length: 52 inches
Height: 26 inches

Not designed for loads such as concrete or bricks.
Only five cubic feet of storage room.
The design does not cater to a dumping motion to remove the load. The contents will simply fall onto the frame and wheel of the wheelbarrow.

$100 USD

http://www.thenarrowbarrow.com 09/12/12
APPENDIX B - SURVEY

WHEELBARROW CUSTOMER SURVEY

This survey’s objective is to gather information regarding a Senior Design project aiming to redesign the wheelbarrow. This survey addresses important design factors in hopes of finding out what is most desirable to the customer.

How important is each feature to you for the design of a new wheelbarrow?
Please circle the appropriate answer.  1 = low importance  5 = high importance

<table>
<thead>
<tr>
<th>Feature</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>N/A</th>
<th>Avg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety</td>
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<td>2</td>
<td>3(1)</td>
<td>4(8)</td>
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<td>5(2)</td>
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</table>

How satisfied are you with the current wheelbarrow?
Please circle the appropriate answer.  1 = very Unsatisfied  5 = very satisfied

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<tr>
<th>Feature</th>
<th>1</th>
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<th>4</th>
<th>5</th>
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How much would you be willing to pay for a new wheelbarrow?

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Thank you for your time.
## Appendix C – Quality Function Deployment

| Kevin Wagner  
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<tr>
<td>1 = Weak</td>
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<th>Width</th>
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<th>Bucket Size</th>
<th>Standard Components</th>
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APPENDIX D – PRODUCT OBJECTIVES

This list represents a plan to satisfy the customer requirements. The design for a powered wheelbarrow will meet most, if not all of these objectives in order to be the best product for the customer.

1) Durability (13%)
   a) Design factor consistent with loading conditions in expected use
   b) Rust-resistant material selection or coated with weather resistant coating
   c) Mudguards
   d) Metal bucket for best impact resistance with tools (shovels, etc)

2) Ease of Unloading (13%)
   a) Dumping assistance
      i) Designed to dump load without tipping the wheelbarrow itself

3) Maneuverability (11%)
   a) Motor assists, when needed, with maneuvering heavy loads
   b) Able to turn 360° without moving forward or backward
   c) Can fit through standard 30” doorway

4) Safety (10%)
   a) Dead man switch for throttle
   b) Hand brake to control speed going downhill, sized to grade and weight
   c) Guards or signs for all moving parts
   d) Guards or signs for all pinch points

5) Cost (10%)
   a) Final prototype cost is less than $1,000

6) Low Maintenance (10%)
   a) No oil change on motor
   b) No lubrication of bearings

7) Capacity (10%)
   a) Minimum of 5 cubic foot capacity
   b) Capable of hauling 200lbs

8) Ease of Operation (9%)
   a) Controls will be standard types
      i) Grip handle, ON/OFF switch, push button
   b) Controls are within normal range of human operation according to human factors for normally functioning adult

9) Comfort (8%)
   a) Consistent with commercial wheelbarrow comfort
   b) Controls will be standard comfort

10) Ease of Cleaning (5%)
    a) Water proof materials
    b) Motor and drive system protected from debris (both from cleaning and from carrying a load)
    c) Drive components above axle
    d) Motor is either covered or removable for cleaning
Appendix E3
APPENDIX F – CALCULATIONS

Lift System Calculations

\[ M = F \times d = 125\,lb \times 7\,in = 875\,in\,lb \]

\[ C = \frac{2}{\text{Height}} = \frac{2}{1.5\,in} = 0.75\,in \]

\[ \sigma_{max} = \frac{MC}{I} = \frac{875\,in\,lb \times 0.75\,in}{0.299\,in^4} = 2195\,psi \]

\[ N = \frac{Sy}{\sigma} = \frac{36\,ksi}{2.19\,ksi} = 16 \]
Front Lift Assembly Calculations

\[ A = h \times w = 0.125in \times 0.5in = 0.0625in^2 \]
\[ \Sigma F_x = -F_1 \cos(64.62^\circ) + 250lb \cos(88.26^\circ) = 0 \]
\[ F_1 = 17.7lb \]
\[ \Sigma F_y = -250lb \sin(88.26^\circ) + F_1 \sin(64.62^\circ) + F_2 = 0 \]
\[ F_2 = 234lb \]
\[ \sigma = \frac{F_{\text{max}}}{A} = \frac{234lb}{0.0625in^2} = 3,742psi = 3.742ksi \]
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Kevin Wagner
Powered Wheelbarrow
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