Hydraulic Machinery Jack

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ABSTRACT

After doing a thorough research of the different types of jack available in the market and performing a survey, a list of characteristics was made to define the different qualities of a jack. In addition to the list of characteristics, a QFD matrix is used to help rank the different desired qualities of a jack. The combination of these two tools is used to come up with different designs for a new and improved jack. Three different designed were fabricated: the platform, the fork, and the table. Then using a decision matrix to determine the best design, the fork was most favorable. After the decision was opted for the fork, the details were worked out and calculations were made to decide on the best materials for the fork as well as the final dimension of the complete jack. Once all the final details were worked out on paper, several weeks were spent in the shop to physically make the jack. The process of making the jack includes measuring, cutting, buffing, drilling, and welding. Following the completion of the jack, the testing process began. Different testing methods included lifting capacity, time of assembly, max height lifted, and storage dimensions. The jack overall has accomplished the characteristics that were define at the start of the project. Comparing the preplanned schedule and to the actual schedule, there were several parts of this project that took longer than planned. Things did not go quite as smoothly as planned, but they were all completed which is the most important goal. With completion of the project, overall it was not too expensive because several materials used for the project were donated. Even if the donated materials were bought out of pocket, the jack would still have cost $248.10, which is still less than the original estimate. Overall the project has turned out well; the jack is completed and has met most if not all the qualities expected of a lifting device.
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INTRODUCTION

Lifting devices come in different shapes and sizes, and there are three types of lifting devices. One type lift such as the farm jack, but it is a non-moveable device. It is not very stable for lifting without someone holding on to it. Also it must be placed on hard ground for the device to be used. Other machines like the pallet mover or the forklift have the ability to lift, but they must have a pallet to hold parts stable so they do not fall while moving them. It is also for working indoors only and these devices are quite expensive. The third type is a device like the bottle jack; it needs to be applied in some form for a useful need like hydraulic cranes, engine hoists, or a wide variety of applications for mechanics, truckers, and farmers.

EXISTING PRODUCTS

Figure 1 is a Farm Jack, a jack that can only lift up to a maximum of one foot. After reaching the maximum height, the load must be lighter than 7000 pounds because it will tilt and become unstable. This device has a small base and will sink into the ground. See the Appendix A for more details.

Figure 01 - The Farm Jack

Figure 2 is on the right side is another example of another type of jack. This jack alone will not be of much help. It has limited travel lift distance. It can lift very heavy objects but cannot move the object from point A to point B unless it is applied to something else like hydraulic cranes, engine hoists, or a wide variety of applications for mechanics, truckers, and farmers. See the Appendix A for more details.

Figure 02 - Eight Ton Hydraulic Round Bottom Jack
Figure 3 is the third example of a hydraulic jack. It is a very reliable device that is easy to push and pull but has one limitation. This device is not usable without a pallet. It is only good for indoor usage such as in a warehouse because this pallet mover has small wheels and so it is easy to sink in soft grounds. Plus it also has limited travel and lift distance. See the Appendix A for more detail.

Figure 4 is another example of a jack that is similar to the one in Figure 3. This device can push and pull as well, but again it has limitations. Lifting without a pallet will cause the jack to become unstable and dangerous to pull or push. The lift distance of this device is not very high. It is only good for indoor use as the Boman Model. Plus it is very expensive, about three times more than the model in Figure 3. See Appendix A for more details.

As for people who work on their farms, it is often hard to move large objects or lift them. A farmer like Mr. Conrad has difficulties with finding tools that can lift heavy loads and also be stable at the same time. A problem he usually encounters has to use multiple jacks to raise a heavy load as well as several blocking events to allow the jacks to be repositioned. This is done in an effort to counter the problem when the jack reaches its extension limit. See the Appendix A for more details.
From a user to a builder, meet Brian Denterlien another interviewee from the College of Applied Science. Brian Denterlein’s CAS senior project in 2007 designed a Lift Cart which uses a hand winch and cable system. It has a lift platform that can move up and down into the groove of the tracks inside of the frame. The lifting platform has two inch diameter rollers mounted to the outside of each of the two platform members. The rollers allow the platform to move up and down without rubbing on the frame. This device can lift from 30 inches to 48 inches in height. The platform is a conveyor, so it is easy to unload. The lift cart has four wheels so it is easy to push round from point A to point B. The cart has a maximum loading capacity of 3000 pounds, and is designed using safety factor of 2. See the Appendix A for more detail.

After researching on the existing products, it is important to understand how much different products cost and their capacities. See the Table 1 below for more details.

Table 1 - The Existing Products

<table>
<thead>
<tr>
<th>Product Name</th>
<th>Costs ($)</th>
<th>Loading capacity (lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farmer jack</td>
<td>29.99</td>
<td>7000</td>
</tr>
<tr>
<td>8 Ton Super Heavy Duty Long Ram Hydraulic Round Bottom Jack</td>
<td>59.99</td>
<td>16000</td>
</tr>
<tr>
<td>Boman Model 2000</td>
<td>329</td>
<td>5500</td>
</tr>
<tr>
<td>Model 82303A</td>
<td>1,069.74</td>
<td>2000</td>
</tr>
<tr>
<td>Easy Lift</td>
<td>674.49</td>
<td>500</td>
</tr>
</tbody>
</table>

CUSTOMER FEEDBACK

Before the survey was handed out, a list of customer features was made to see which features are most important to consumers. The different features are rated from 1 (least important) to 5 (most important). Surveys were sent to four customers who worked in a machine shop, two people who are farmers, and the rest are students who own a common jack for general use such as for changing of tires. Here is the average of the scores listed from most important to least important in ranking.
1. Capacity 3.6  
2. Strong frame 3.4  
3. Stability 3.2  
4. Compact storage 3.0  
5. Easy to assemble 2.1  
6. Easy to maneuver 1.6  
7. Light weight 1.2  
8. Easy to repair 1.1  
9. Quiet operation 1.0  
10. Cost 0.8

The next list is the results of the customers’ satisfaction with their current lifting devices listed from least important to most important characteristics.

1. Cost 0.6  
2. Quiet operation 0.6  
3. Easy to repair 1.0  
4. Easy to maneuver 1.0  
5. Light weight 1.0  
6. Easy to assemble 2.1  
7. Compact storage 2.5  
8. Stability 2.9  
9. Capacity 3.3  
10. Strong frame 3.4

Overall the four most important features to customers are a strong frame, capacity, compact storage, and stability while loading. Dissatisfaction is found in the areas of cost, easy to repair, lightweight, easy to assemble, and quiet operation. For more details on the survey results look at Appendix B.

**Figure 06 - Hydraulic Machinery Jack versus Current Lift**

![Graph showing comparison between Hydraulic Machinery Jack and Current Lift](image.png)

*Figure 06 - Hydraulic Machinery Jack versus Current Lifting Device*
Looking at Figure 7 above is a good way to analyze and compare the current lifting device to the Hydraulic Machinery Jack. The points for the Hydraulic Machinery Jack based on the survey are higher than the Current Lifting Devices. The highest points from Figure 7 are the capacity, strong frame, and stability for both the Hydraulic Machinery Jack and the Current Lifting Device. The points of greatest differences between the Hydraulic Machinery Jack and the Current Lifting are storage capacity, ease in maneuver. Comparisons between the two will aid in qualities needed to improve for the Hydraulic Machinery Jack.

QUALITY FUNCTION DEPLOYMENT (QDF) RESULTS

The list below is the QFD matrix in Appendix C, the result for the engineering characteristics are arranged in order from the most important to the least important. Rigid material is the highest feature with 1.60, which refers to the durability of the product. The second highest is one-person operation with 1.35. This second most looked for factor is the ability for the equipment to be operated by one person; in this way users save money and time, being able to avoid asking or hiring others for help. The third most important is the quiet operation with 0.58. Each of the factors is listed in order of most to least importance.

1. Rigid material 1.60
2. One-person operation 1.35
3. Quiet operation 0.58
4. Range of loads 0.49
5. Design factor 0.49
6. Weight of device 0.41
7. Easy assembly 0.38
8. Compact device 0.35
9. Cost of material 0.30

PROOF OF DESIGN

1. Rigid material – Choosing the right materials for the jack is important because the jack has to last for a while and be made of durable materials to handle and support lifting different objects.

2. One-man operation – Since the device is able to lift up to 40 inches with heavy load, it saves time and money when a job requiring several people or an expensive machine can be done with only one person and a device.

3. Quiet operation – Devices with wheels make less noise during operation and in addition this jack uses hydraulic power, which makes no sound at all if one would compare it to the winch lift.
4. Range of loads – This Hydraulic Machinery Jack is estimated to have a capacity of lift anything from 1000 to 4000 pounds.

5. Design factor – For this project, the safety factor of 3 was picked, which was based on material section knowledge and operating condition.

6. Weight of device – This device weighs 228 pounds, which is similar to the existing products in the market.

7. Easy assembly – The whole device will be made in a very simple shape from commercially available products which can easily be replaced if parts wear out.

8. Compact device – This device will have a base space of 16 inches by 16 inches and a height of 55 inches tall when it is fully installed assembled. This jack can easily be disassembled if needed for storage.

9. Cost of materials – The whole device costs $248.10, which is affordable for a general device that can lift and move.

ALTERNATIVE DESIGNS

After researching about the current lifting device available in the market as well as considering the important features rated by consumers through the survey, three designs were fabricated: the platform, the table, and the fork. Then comparing the different features of each design doing the decision matrix, the fork design was chosen as the final design for the Hydraulic Machinery Jack.

THE PLATFORM

The device shown in Figure 8 is a platform lifting device. The platform for which objects can be placed is built between the two long circular bars standing along the side of the hydraulic jack pump. As the jack pushes against the platform, the platform will move up along the two circular bars until it reaches the top.
One flaw of this design is that if one of the bars is broken the whole jack becomes useless because the platform is dependent upon the two bars to guide it up and down. The whole device is welded together. This jack also has its limits in traveling distance, the platform cannot move all the way to the base because the jack is in the way. It has a small base and is immobile; it is also noisy and may not last long because the platform will wear out as it rubs on the two bars.

**THE FORK**

The device shown in Figure 9 is the fork lifting device. This is a good design since the fork is short and not too wide allowing support of objects without getting bent so easily.
Objects are lifted up by a jack with a nylon strap. One end of the strap is attached to the base of the jack and the other end is attached to the fork. There is a roller on top of the jack that will help keep the strap in line as well as facilitating the movements of the strap by decreasing friction between surfaces and reduce tearing of the strap. The roller will also reduce noise volume because of smooth movements of the strap. On each side of the fork will be two wheels to guide the fork up and down the c-channel steel. This will also reduce the potential sounds during operation of the jack. Another advantage is that this jack is moveable and can be disassembled if needed for storage because the whole device has bolts and nuts that hold the major components together.

**THE TABLE**

The third device in Figure 10 is the table lifting device that also uses the hydraulic jack. The jack is welded to the base, and then it is welded to another square frame just big enough to fit the top of the hydraulic jack. Next there are square bars that are welded at the four corners of the base connecting to the corners of the base sheet. The table is welded to the top of the cylinder of the jack which serves as a platform for objects to be placed.

![Figure 10 - The Table](image)

One flaw in the design is if one of the parts is broken, the whole jack is useless. The whole device is welded together so one cannot disassemble it if needed. Also this jack has its limits in travel distance if you want to lift something from ground level. The device is not moveable; this jack must be physically lifted to move from point A to B.
THE DECISION MATRIX

Table 2 - Decision Matrix

<table>
<thead>
<tr>
<th>Design Criteria</th>
<th>weights Factor</th>
<th>Unit</th>
<th>Magnitude</th>
<th>Score</th>
<th>Rating</th>
<th>Magnitude</th>
<th>Score</th>
<th>Rating</th>
<th>Magnitude</th>
<th>Score</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strong frame</td>
<td>0.16</td>
<td>High/Medium/Low</td>
<td>High</td>
<td>5</td>
<td>0.79</td>
<td>High</td>
<td>5</td>
<td>0.7915</td>
<td>High</td>
<td>5</td>
<td>0.79</td>
</tr>
<tr>
<td>Capacity</td>
<td>0.16</td>
<td>High/Medium/Low</td>
<td>High</td>
<td>5</td>
<td>0.82</td>
<td>High</td>
<td>5</td>
<td>0.824</td>
<td>High</td>
<td>5</td>
<td>0.82</td>
</tr>
<tr>
<td>Stability</td>
<td>0.16</td>
<td>High/Medium/Low</td>
<td>Low</td>
<td>1</td>
<td>0.16</td>
<td>Low</td>
<td>1</td>
<td>0.1638</td>
<td>Low</td>
<td>1</td>
<td>0.16</td>
</tr>
<tr>
<td>Easy to assemble</td>
<td>0.13</td>
<td>Yes/No</td>
<td>No</td>
<td>1</td>
<td>0.07</td>
<td>Yes</td>
<td>5</td>
<td>0.3287</td>
<td>No</td>
<td>1</td>
<td>0.07</td>
</tr>
<tr>
<td>Easy to repair</td>
<td>0.12</td>
<td>High/Medium/Low</td>
<td>Medium</td>
<td>3</td>
<td>0.49</td>
<td>High</td>
<td>5</td>
<td>0.8189</td>
<td>Medium</td>
<td>3</td>
<td>0.49</td>
</tr>
<tr>
<td>Easy to maneuver</td>
<td>0.07</td>
<td>Yes/No</td>
<td>No</td>
<td>1</td>
<td>0.13</td>
<td>Yes</td>
<td>5</td>
<td>0.6301</td>
<td>No</td>
<td>1</td>
<td>0.13</td>
</tr>
<tr>
<td>Compact</td>
<td>0.07</td>
<td>High/Medium/Low</td>
<td>Low</td>
<td>1</td>
<td>0.07</td>
<td>Medium</td>
<td>3</td>
<td>0.2156</td>
<td>Medium</td>
<td>3</td>
<td>0.22</td>
</tr>
<tr>
<td>Light weight</td>
<td>0.06</td>
<td>High/Medium/Low</td>
<td>Medium</td>
<td>3</td>
<td>0.19</td>
<td>Low</td>
<td>1</td>
<td>0.0641</td>
<td>Medium</td>
<td>3</td>
<td>0.19</td>
</tr>
<tr>
<td>Quiet operation</td>
<td>0.04</td>
<td>High/Medium/Low</td>
<td>Medium</td>
<td>3</td>
<td>0.11</td>
<td>Medium</td>
<td>3</td>
<td>0.112</td>
<td>Low</td>
<td>1</td>
<td>0.04</td>
</tr>
<tr>
<td>Cost</td>
<td>0.03</td>
<td>High/Medium/Low</td>
<td>Medium</td>
<td>3</td>
<td>0.10</td>
<td>Medium</td>
<td>3</td>
<td>0.099</td>
<td>Medium</td>
<td>3</td>
<td>0.10</td>
</tr>
</tbody>
</table>

The table above is the weighed decision matrix. The result that makes the fork has the highest ratings than the table and platform is because the Fork has high scores five different areas: easy to repair, easy for assemble, easy to maneuver, compact, and quiet operation. The fork is easy to repair because it is made from commercially available parts so if one component is broken and need to be replaced it can easily be fixed. Major components of the fork are held together by nuts and bolts so it is easy to assemble compared to the table and platform. Since the major parts of the fork can easily be taken apart, it makes it easier and more convenient to store the device in little spaces. In addition this feature allow for easy maneuverability because one can just take the fork apart and move it to wherever is desirable and reassemble it back together. The platform and the table cannot be taken apart because they are all welded together. The fork has good rating on quiet operation because it uses a hydraulic jack and no major parts are rubbing against one another to make a lot of noise like the platform.

GENERAL CALCULATIONS

In order to make sure the Hydraulic Machinery Jack is stable, it is important to calculate the center mass of this jack to see if it could withstand the heavy load without tipping over. The free body diagram in Figure 11 shows where the center mass of the Hydraulic Machinery Jack and where is the appropriate length to apply the load on the fork.
The most important thing for this project is to avoid tipping over when applying a heavy load. After all the calculations were made, there are two results for the fork length which are 20 inches from center mass to the right side and 11 inches to the left from the center mass. As long as the fork length is in the limit then it is safe to pick a distance for the fork. For this project the fork length is 6.25 inches. See the Appendix E for more details on calculations.

To ensure that the Hydraulic Machinery Jack is stable while applying the loading force, it is important to calculate the bolts strength so it could withstand heavy loads without being sheared. Figure 12 and 13 show where the forces affect the bolts that hold the frame of the Hydraulic Machinery Jack.
Figure 12 - Force applied affecting the bolts

Figure 13 - Free body diagram showing the forces affecting the bolts
Table 3 - SAE Grades of the Steel for Fasteners

<table>
<thead>
<tr>
<th>Grade number</th>
<th>Bolts size in</th>
<th>Tensile strength ksi</th>
<th>Yield strength ksi</th>
<th>Proof strength ksi</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>1/4-1</td>
<td>120</td>
<td>92</td>
<td>85</td>
</tr>
<tr>
<td></td>
<td>&gt;1-1 1/2</td>
<td>105</td>
<td>81</td>
<td>74</td>
</tr>
<tr>
<td>6</td>
<td>1/4-1 1/2</td>
<td>133</td>
<td>115</td>
<td>105</td>
</tr>
<tr>
<td>7</td>
<td>1/4-1 1 1/2</td>
<td>150</td>
<td>130</td>
<td>120</td>
</tr>
</tbody>
</table>

After doing the calculation for the bolts, the result is 0.487 inch diameter and the diameter selected was 0.50 inch. The material for the bolt is selected from Table 3. SAE grade 5 with the proof strength of 85,000 psi, tensile strength of 10,000 psi and yield strength of 95,000 psi. See Appendix E for more details on the calculation.

In order to make sure the fork of Hydraulic Machinery Jack is rigid while applying the loading force, it is important to calculate the tubing strength of this jack so it could withstand the force without being bend or broken. Figure 14 and 15 show where the force affects the tubing of the Hydraulic Machinery Jack.
Based on the calculation results, the size of the tubing for the fork was selected. The material picked is steel A500 ASTM shape grade C with a $50 \times 10^3$ psi for yield strength and the chosen length of load on the fork is 6.25 inches. The only one that came close to the Section Modulus value for structural tubing is 2x2x1/4. See Appendix E for more details on calculation.

In order to make sure the fork joiner of Hydraulic Machinery Jack is rigid while applying the force. It is important to do this calculation so the circular bar could withstand the force pulling up by the nylon strap without being bend or broken. Figure 16 and 17 show where the force affects the circular bar of the fork joiner.
Based on the calculations, the result for the fork joiner is 1.18 inch. The chosen diameter for the steel bar is 1.25 inches. The material selected for the fork joiner is AISI 1137 OQT 400. For this application, it is best to have the circular bar instead of the square bar because the nylon strap would wear out more quickly due to the sharp edges of the square. See Appendix E for more details on the calculation.

In order to make sure the bolt of the fork is rigid while applying the loading force, it is important to calculate the bolts strength so when force was applied on the fork it can withstand it without being bend or broken while moving up or down in the frame. The Figure 18 and 19 are show where the forces affect those bolts.
Based on the calculations, the result of the bolts for the fork is 0.15 inch. The diameter for the bolt that was chosen is 0.50 inch. The material for the bolt is SAE grade 5 with proof 85,000 lb/in², tensile strength $S_u$ of 120,000 lb/in², and ultimate shear strength $S_{us}$ of 69,700 lb/in². The diameter that works for this project is 0.50 inch diameter. The reason for picking a large diameter is because people do not always know how heavy the objective that they are lifting. See Appendix E for more details on the calculation.

In order to make sure the sheet of the roller is rigid while applying the loading force, it is important to calculate the wall thickness that have the strength to withstand the force without being bend or broken while the nylon strap pulls down during operation. The Figure 20 and 21 show where the force affects the wall thickness of roller component.

Figure 19 - Free body diagram show how the bolts react when apply force.

Figure 20 - Component of the roller on bending
Figure 21 - Free body diagram on component of roller

The result for the thickness of this component is 0.17 inch. The dimensions of the sheet steel that was selected are a length of 5 inches, height of 1.75 inches, and thickness of 0.50 inch. The material that is chosen for the roller is AISI 1020 hot-rolled with yield strength of 30,000 psi and tensile strength of 55,000 psi. See Appendix E for more details on the calculation.

In order to make sure the bolts of Hydraulic Machinery Jack is rigid while applying the loading force, it is important to calculate the bolts strength so when the force was applied on the roller, it could withstand it without being bent or sheared. The Figure 22 shows where the force affects the bolts.

Figure 22 - Shear bolts of the roller

The diameters that can hold up the load from shear is 0.15 inch diameter but for real application it is hard to find such a small bolt so the actual size of this bolt will be 0.50 inch diameter. The material for the rod of the roller is SAE grade 5 and the shear stress is 69,700 psi. This was provided by the sponsor. See Appendix E for more details on the calculation.

In order to make sure the base of Hydraulic Machinery Jack is rigid while applying the loading force. It is important to calculate the strength so when the force was applied on the
base, it could withstand the force without being bent or broken. The Figure 23, 24 and 25 show where the force affects the L-shape base.

Figure 23 - Force applied at the front of the base

Figure 24 - Top view of the base
Based on the calculations for the worst case scenario, the section modulus is 1.07 in$^3$, the only L-shape material that was the closest is L-3X2½X5/16. The material is ASTM A514 quenched and tempered with yield strength of 100,000 psi and tensile strength of 115,000 psi. See Appendix E for more details on the calculation.

**FABRICATION**

Almost everything used for this project is made from commercial products: c-channel, steel sheet, nylon strap, chain, and steel bar. The process of making this Hydraulic Machinery Jack was done in the school workshop: welding, drill hole, cutting, grinding, measuring, and turning.

**ROLLER**

The roller is for reducing friction when the nylon strap is moved by the jack rising up or moving down. This roller has eleven components: a center block, two metal sheets, two axles, two nylon cylinders, two bolts, and two nuts. The center block was cut to size and has
one drilled hole on the bottom. The hole is big enough to set the roller on the small cylinder of the jack. The center block was welded to two metal sheets front and back; it was cut to size and has two drilled holes on each side. The two drilled holes fit two axles on each side of the center block for the nylon cylinders. The axle is a very tight fit and smooth to reduce friction and easy for nylon cylinder to rotate. Finally the nuts and bolts are fastened.

**Bracket**

![Figure 27 - The Bracket](image)

The bracket is another component of the Hydraulic Machinery Jack. The bracket was cut to size and has drilled holes in which 24 set of nuts and bolts are fitted. One side of the brackets help hold the two parallel bars which make up the frame of the jack stand on the base securely and the other side that face down is then fasten to the base.

**Fork**

![Figure 28 - The Fork](image)

The fork is a component of the Hydraulic Machinery Jack; its purpose is to hold the load. The fork was made of four square tubes that were cut to size and welded together perpendicularly; a triangle steel sheet was also welded to the square tubes for extra support. Then on each side of the fork were two wheels attached by nuts and bolts. Parts of the
wheels include the axles, spacers, and tires. The wheels were machine to size, drilled, and buffed smoothly to rotate along the inside of the c-channel steel when the fork is moving up and down. The wheels need grease on the axle’s surface for the tire to rotate easily. The wheels are used for guiding the fork vertically either up or down in the c-channel steel. Using the wheels instead of plain metal bars reduce noise and friction. The top two bolts that hold the top two wheels are also used to attach two chains, which is another feature for security just in case if a load is too heavy and the nylon strap fails. One end the chain is attached to the two top bolts and the other end is attached to the steel c-channel frame at the top. The nylon strap is attached to the fork joiner, over the roller, and then down to the back of the jack. It is then wrapped around a hexagon block.

\textbf{BASE}

![Figure 29 - The Base](image)

The base is the most important component for the entire jack; it is the foundation of the jack. The base is made from L-shape steel, cut to size, and welded together. It has multiple drilled holes to fasten other components with nuts and bolts including the frame, base metal sheet, and the hexagon block.

\textbf{FRAME}

![Figure 30 - The Frame](image)
Another component of the Hydraulic Machinery Jack is the frame. The frame of this jack has two useful purposes. One is to guide the moving fork in the correct position (up or down), and two is to hold the load if the nylon strap failed. The c-channel was cut to size and welded to the base metal sheet. The c-channel has two slots and holes cut out at the top for the chain to attach on.

**ASSEMBLY**

![Tools for assembly](image)

To completely assemble the different components of the Hydraulic Machinery Jack together, one would need one tool pin, either a socket wrench, a combine wrench, or an adjustable wrench. Use the tool pin for the wheel and the wrench for any place that is needed to adjust the nuts and bolts. To assemble the jack together, first put the steel sheet on top of the base. Then bolt down the two c-channel steels that make up the frames on to the base metal sheet. Next slide the fork with its wheels in the track of the c-channel frame from the top down, and then fasten the top metal piece that runs horizontally on top of the two c-channel steels. Next insert the jack in between the fork and place the roller on top of the jack. The last step is to attach the nylon strap to the fork joiner. The nylon strap is pulled over the roller then back down to the back. The nylon strap is wrapped around the hexagon block then bolted down to the base.

**TESTING METHODS**

Several tests were performed to ensure safety and quality of the jack. Minor tests include assembly time, ease of operation, storage areas, weight of individual parts, and extension height of the jack. The most important and difficult test was the lifting capacity of the jack.

To test for ease of assemble and disassemble, three trials with three different people...
trying to put the jack together and record the time it takes for each individual to complete the task. The average time it takes to assemble or disassemble is twenty minutes. Then two trials for the ease of operation are performed with two different people. Instructions are given to each person and the time it takes for each person to operate the jack is recorded. The average time it takes for a person to operate the jack is less than three minutes. A third test is for storage. One person disassembles the jack and then stores the components of the jack in a garage or the back of a truck. Measurement of the space needed to store all the components of the jack is taken. To store all the parts in a vertical position against the wall, it takes 12 x 24 inches and to store it in a horizontal position on the ground it takes 24 x 55.5 inches. Each component is weighed on a scale; the heaviest part is the base, 82 pounds, and all the other components are less than 50 pounds each. The extension height of the jack was also assessed. The highest height in which the jack can lift is 40 inches off the ground.

**TEST 1: SEMI-TRUCK TRAILER - LIFTING CAPACITY**

![Figure 32 - Lift semi-trailer](image)

One of the most important tests in this process is the lifting capacity of the jack. In the calculations, the jack was calculated to lift a maximum weight of 4,000 pounds or two tons. This test was done to see how heavy of a load the jack is able to lift. The test was performing in the parking lot of the College of Applies Science lifting a semi-trailer. The jack was able to lift the semi-trailer a quarter of an inch above the ground; the semi-trailer was way too heavy for the Hydraulic Machinery Jack. Unfortunately a scale large enough to weigh the semi-truck was not available to obtain the exact weight of the semi-trailer so all that is available are statistics obtained through experts who worked at Truck Sale, a company that sells trucks and semi-trailers. Of course this is a major limitation in this test. According to these experts at the Truck Sale, an empty semi-trailer weights 11,000 pounds. According to the manufacture of the nylon strap, the maximum capacity of the nylon strap is five thousand pounds, but the semi-trailer is eleven thousand pound. So when lifting the semi-trailer only a
quarter of an inch of the ground, it is not surprising that the nylon strap has stretched out two inches. The strap endured a weight that is over the limit of its maximal capacity.

**TEST 2: TRUCK BED – LIFTING CAPACITY**

![Figure 33 - Lift truck bed](image)

A second lifting capacity test was performed at Mr. Conrad’s farm. In this test, the jack lifted a full truck bed that was used as an outdoor storage; it is smaller than the truck bed. The test result was a lot better than the previous test on the semi-trailer. The jack was able to lift the truck bed two inches of the ground for about five minutes, long enough to fill some dirt underneath the truck bed. Then truck bed was put down and the jack was taken out. After the jack was pulled out and inspection of the nylon strap was performed, the nylon strap was torn a little which indicated that the truck bed was more than four thousand pounds because the maximum capacity of the nylon strap is 5,000 pounds. If it is less than 5,000 pounds, the nylon strap would not have torn the way it did. Once again there is no scale available to weigh such a large object as the truck bed which makes it a major limitation to the test, so only a rough estimate can be made in comparison to the semi-trailer. With this truck bed being smaller but is full in contents, it estimated to weigh between 6,000 to 7,000 pounds.

**TEST 3: LOAD CELL – LIFTING CAPACITY**

A third lifting capacity test was performed at school workshop with a new nylon strap that has a 20,000 pound capacity. This time the test was a lot accurate than the two previous tests. This time the load used was load cell on a steel bar. Then a second steel bar was put on top of the load cell. This steel bar was tied to a nylon strap that to prevent the load cell from moving. In this test, the jack lifted at 2000 psi (which is 2000 pounds per square inch) by using the load cell and the fork did not break or bend; the nylon strap was in good condition as well after lifting the load cell. Then a second trial to lift 4,500 psi was done and once again the fork was able to lift the load cell without any problem. The nylon straps did not stretched or tore after lifting this load.
Figure 34 – Load cell

Figure 35 – Load cell at 2000 psi

Figure 36 – Load cell at 4500 psi
TIME MANAGEMENT

In summary this project took several months to complete. It took eleven weeks in the winter quarter just to design the device, do the calculations, and order the necessary materials. Table 4 shows the planned schedule in blue and the actual time to complete each task in green. It took an extra week to complete all the tasks. The estimated time to complete each task was two weeks, but the actual time it took to fully accomplish the task was three weeks. In the spring quarter, it took almost nine weeks to build the project. This project was also set back because the school workshop was not available for students to work for the first three weeks of the quarter. So three weeks of the quarter was lost and delayed, but the final product was finished before the TechExpo and there was still enough time for demonstrations and testing to make sure that it works properly. See Table 4 for more details.
### Table 4 - Schedule

<table>
<thead>
<tr>
<th>Task</th>
<th>Winter Quarter</th>
<th>Spring Quarter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preselection of the design</td>
<td>1/7-1/11</td>
<td></td>
</tr>
<tr>
<td>Preselection of the design</td>
<td>1/14-1/18</td>
<td></td>
</tr>
<tr>
<td>Proof of design</td>
<td>1/21-1/25</td>
<td>4/11-4/18</td>
</tr>
<tr>
<td>Design the device</td>
<td>1/28-2/1</td>
<td>4/22-4/25</td>
</tr>
<tr>
<td>General Calculation</td>
<td>2/4-2/8</td>
<td>4/28-5/2</td>
</tr>
<tr>
<td>Design freeze</td>
<td>2/25-2/29</td>
<td>5/27-6/1</td>
</tr>
<tr>
<td>Oral design presentation</td>
<td>3/3-3/7</td>
<td>5/27-6/13</td>
</tr>
<tr>
<td>Prepare design report</td>
<td>3/10-3/14</td>
<td>6/1-6/13</td>
</tr>
<tr>
<td>Prepare design report</td>
<td>3/22-3/30</td>
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<tr>
<td>Design report due</td>
<td>3/31-4/4</td>
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</tr>
<tr>
<td>Spring break</td>
<td>4/7-4/11</td>
<td>6-6/13</td>
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<tr>
<td>Build frame</td>
<td>4/14-4/18</td>
<td></td>
</tr>
<tr>
<td>Build frame</td>
<td>4/21-4/25</td>
<td></td>
</tr>
<tr>
<td>Build fork</td>
<td>5/2-5/6</td>
<td>6/13</td>
</tr>
<tr>
<td>Build fork</td>
<td>5/22-5/27</td>
<td></td>
</tr>
<tr>
<td>Build bracket</td>
<td>5/30-6/4</td>
<td></td>
</tr>
<tr>
<td>Build base</td>
<td>5/5-5/13</td>
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<tr>
<td>Build base</td>
<td>5/15-5/20</td>
<td></td>
</tr>
<tr>
<td>Build rollers</td>
<td>5/16-5/27</td>
<td></td>
</tr>
<tr>
<td>Build rollers</td>
<td>5/30-6/4</td>
<td></td>
</tr>
<tr>
<td>Assemble parts</td>
<td>6-6/13</td>
<td></td>
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<tr>
<td>Assemble parts</td>
<td>6-6/13</td>
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</tr>
<tr>
<td>Demonstration</td>
<td>11-Mar</td>
<td>22-May</td>
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<tr>
<td>Demonstration</td>
<td>21-Mar</td>
<td></td>
</tr>
<tr>
<td>Correct problems</td>
<td>18-Feb</td>
<td>22-May</td>
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<tr>
<td>Tech EXPO</td>
<td>11-Jun</td>
<td></td>
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<tr>
<td>Work on final report</td>
<td>11-Jun</td>
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<tr>
<td>Oral presentation</td>
<td>22-May</td>
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<tr>
<td>Oral presentation</td>
<td>28-May</td>
<td></td>
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<tr>
<td>Report due</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
BUDGET MANAGEMENT

The estimated budget needed to complete the project is about $430.00. The actual budget also considering the costs of the items donated by the generous sponsor is $248.10. This is without considering the labor cost because school provides the workshop free to use with tools and machines included. The cost of the project minus the donated parts is $191.10. The most expensive item spent on this project is the c-channel steel for the frame. The long c-channel steel frame was expensive because the product was sold at a certain length. All other parts were less than fifty dollars. Thanks to the generosity of the sponsor for providing many of the required parts of the projects, the budget was cut down tremendously.

Table 5 - Estimate/Actual Budget

<table>
<thead>
<tr>
<th>Estimate schedule</th>
<th>Estimate schedule</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Frame</td>
<td>$200.00</td>
<td>C-shape/L-shape/square tubing/steel sheet</td>
</tr>
<tr>
<td>Lift mechanism</td>
<td>$65.00</td>
<td>Hydraulic jack Provided</td>
</tr>
<tr>
<td>Load platform</td>
<td>$50.00</td>
<td>Nuts/bolts/washers $24.21</td>
</tr>
<tr>
<td>Misc. service</td>
<td>$80.00</td>
<td>Nylon strap Provided</td>
</tr>
<tr>
<td>Nuts/bolts/washers</td>
<td>$20.00</td>
<td>Base sheet Provided</td>
</tr>
<tr>
<td>Cable/nylon strap</td>
<td>$15.00</td>
<td>Roller Provided</td>
</tr>
<tr>
<td>Total</td>
<td>$430.00</td>
<td>Fork wheel Provided raw stock</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Brush paint/paint brush $10.34</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Chains $21.24</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total $191.10</td>
</tr>
</tbody>
</table>

CONCLUSION

Completing this project was quite an accomplishment. There were so many steps involved: research, survey, calculations, material selections, procurement of the materials, and building the final project. To complete the whole project in its entirety, almost a whole school year is required for the project. The hardest part to this project was probably designing the jack and doing the calculations on paper. After all the problems were figured out, making the project was not too difficult. Though the proposed schedule did not work out for each step, the final project was completed before the day for TechExpo, and I still have time left to test the device. Overall it was quality time well spent on the project.
REFERENCES

1. Farmer Jack. 10/03/07

2. 8 Ton Super Heavy Duty Long Ram Hydraulic Round Bottom Jack. 10/03/07

3. Boman Model 2000. 10/03/07
   http://www.bomanforklift.com/catalog/product_info.php/cPath/1/products_id/29

4. Model 82303A. 10/03/07
   http://www.hyjacks.com/dolly.htm


# APPENDIX A - RESEARCH PRODUCTS

<table>
<thead>
<tr>
<th>Product Description</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multi-functional tool suitable for lifting tractors or heavy trucks, pulling posts</td>
<td>Easy to assemble&lt;br&gt;Sinks in soft ground&lt;br&gt;Hard to handle when lifting high with loads</td>
</tr>
<tr>
<td>and poles, and even serves as an all-purpose hoist or winch. Ratings establish a</td>
<td>Design: ratcheting&lt;br&gt;Capacity: 3-1/2 ton&lt;br&gt;Maximum Height: 48&quot;&lt;br&gt;Minimum Height: 6&quot;&lt;br&gt;Weight: 30 lbs.&lt;br&gt;Cost: $29.99</td>
</tr>
<tr>
<td>height of 1 foot.&lt;br&gt;Design: ratcheting&lt;br&gt;Capacity: 3-1/2 ton&lt;br&gt;Maximum Height: 48&quot;&lt;br&gt;Minimum Height: 6&quot;&lt;br&gt;Weight: 30 lbs.&lt;br&gt;Cost: $29.99</td>
<td></td>
</tr>
<tr>
<td>Enormous 19-1/4&quot; stroke for jobs requiring a large lift. Baked enamel finish</td>
<td>Light weight&lt;br&gt;Cost low $59.99&lt;br&gt;Can operate by one person&lt;br&gt;Small size&lt;br&gt;Simple to control&lt;br&gt;Easy to install</td>
</tr>
<tr>
<td>piece handle&lt;br&gt;Mount directly onto shop cranes&lt;br&gt;Capacity: 8 ton&lt;br&gt;Max. Height: 44-1/2&quot;&lt;br&gt;Min. height: 24&quot;&lt;br&gt;Stroke: 19-1/4&quot;&lt;br&gt;Shaft diameter: 1-5/16&quot;&lt;br&gt;Pinhole size: 5/8&quot;&lt;br&gt;Weight: 37-1/2 lbs.</td>
<td></td>
</tr>
</tbody>
</table>
Boman manual pallet jacks are designed to be a cost effective way for one person to move material around a warehouse. With various sizes and capacities such as 5500# pallet jacks, we have a pallet jack to fit your need, whether in a large production facility or in a tight space. Each Boman jack is a fully hydraulic pallet jack; it has a stainless steel piston and ram for long use. It is easy to operate with a 3 position handle and polyurethane wheels and rollers for long life and easy rolling.

Model 2000: 5500 lb capacity, 2.9" Lowered Height, 3-position handle

<table>
<thead>
<tr>
<th>Cost high $329</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sinks in soft ground</td>
</tr>
<tr>
<td>Limited height extension</td>
</tr>
<tr>
<td>Light weight</td>
</tr>
</tbody>
</table>

10/03/07
Boman Model 2000
Lift arm tilts 45 degrees for easy wheel bearing installation. 4 Swivel casters, 3 1/4" travel adjustment on rear locking casters to match spindle angle, ball bearing rollers for easy rotating.
Lift - 5-3/4"
Length - 39-1/2"
Width - 41"
Height - 33-3/4"
Shipping wt. 193 lbs
MODEL 82303A, List Price $1,528.21
Our Price $1,069.74

http://www.hyjacks.com/dolly.htm
10/03/07
Model 82303A

Very large
Cost high
Limited capacity
Can not lift high
Work in warehouse only
Mr. Conrad was a farmer and is now a professor at the College of Applied Science College. Mr. Conrad knows how hard it is for a farmer to move things and lift them around the farm having formerly been a farmer. Mr. Conrad has had the experience of hard work on a farm when the equipment was either lacking or incontinent because it lacked the operatives needed to get the job done. Farmers have machines that can lift but the problem is that it can not hold up loads steadily without the use of multiple jacks to raise the loads and several blocking events to allow the jacks to be repositioned as the jacks reach their extension limit. Most farmers use farm jacks to lift but people also have a hard time moving things from point A to point B and this jack can only to lift loads up to a certain height. The job can become very difficult because farm jacks don’t have wheels and has a small base, which is easy to sink into the soft ground.
Brian was a MET student and graduate in the summer of 2006. His senior project was a Lift Cart which uses a hand winch and cable system. The lifting platform would be confined to ride in two grooved tracks running vertically down the inside of the frame. The lifting platform has a two inch diameter rollers mounted to the outside of each of the two platform members. These roller wheels would be confined to the grooved tracks in the frame, and would allow the lift platform to remain horizontal while being raised or lowered by the user. The height of the unit would determine the height in which the load could be lifted. Since most truck beds range from 30 inches, to 48 inches in height, the tracks would allow the lift platform to rise to 52 inches. The tracks would also allow the platform to be lowered all the way to the ground, so that load could be easily inched onto the platform. The lift cart would have a total of four wheels and two handles allowing the user to transport the load from point A to B. The cart would have a maximum loading capacity of 3,000 lbs and be designed using safety factor of 2.

Cost high $674.49

Brian Denterlein
MET UC student
(513) 238-8806
BrinPhd3@aol.com
APPENDIX B - SURVEY RESULTS

Hydraulic High Lift Jack

My name is Kiet Bui. I am attending the College of Applied Science and am currently studying Mechanical Engineering Technology. I want to design a hydraulic jack to lift various objects from close to the ground to more than 20 inches high for my senior design project. Please take a few moments to answer a few questions that will help me design a better jack.

What is important to you for the design of a high lift hydraulic jack? Please circle one for each question below.

1 = low important  5 = high important

Your input will help me design a versatile high lift hydraulic jack.

<table>
<thead>
<tr>
<th></th>
<th>Hydraulic Machinery Jack</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>1 Strong frame</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2 Capacity</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3 Compact storage</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>4 Light weight</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5 Stability</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>6 Easy to maneuver</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>7 Easy to assemble</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>8 Quite operation</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>9 Easy to repair</td>
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<td>0</td>
</tr>
<tr>
<td>10 Cost</td>
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</table>

<table>
<thead>
<tr>
<th></th>
<th>Current Lift</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
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<tr>
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<td>2 Capacity</td>
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<td>3 Compact storage</td>
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<td>4 Light weight</td>
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<td>5 Stability</td>
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<td>6 Easy to maneuver</td>
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<tr>
<td>7 Easy to assemble</td>
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<tr>
<td>8 Quite operation</td>
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<tr>
<td>10 Cost</td>
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</table>

Your input will help me design a versatile high lift hydraulic jack.

Thank you
## APPENDIX C - QFD MATRIX

<table>
<thead>
<tr>
<th></th>
<th>Rigid Material</th>
<th>Compact Device</th>
<th>Weight of Device</th>
<th>Design Factor</th>
<th>One Person Operation</th>
<th>Quiet Operation</th>
<th>Range of Load</th>
<th>Cost of Materials</th>
<th>Easy Assembly</th>
<th>Customer Importance</th>
<th>Satisfaction with Current Cost</th>
<th>Planned Cost</th>
<th>Improvement Ratio</th>
<th>Improvement (Absolute weight)</th>
<th>Relative Weight</th>
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<td>01. Strong frame</td>
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<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>03. Compact storage</td>
<td>3</td>
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<td>04. Light weight</td>
<td>3</td>
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<td>05. Stable while loaded</td>
<td>3</td>
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<td></td>
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<td></td>
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<td></td>
<td></td>
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<td>06. Easy to maneuver</td>
<td>3</td>
<td>9</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.126</td>
</tr>
<tr>
<td>07. Easy to assemble</td>
<td>3</td>
<td>3</td>
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<td>08. Quite operation</td>
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<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.064</td>
</tr>
<tr>
<td>09. Easy to repair</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>10. Cost</td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>0.033</td>
</tr>
</tbody>
</table>

| Absolute Importance | 1.8 0.35 0.41 0.49 1.35 0.58 0.49 0.30 0.38 | 6.2 31.9 1.00 |
| Relative Importance  | 0.30 0.06 0.07 0.08 0.22 0.09 0.08 0.05 0.06 |
| Current Lifts       | 130 2756000 375 |
| Direction of movement | x x ▼ x x x ▼ ▼ x |
| Target Value        | 140 8000 300 |
| Units               | lbs lbs $     |

Appendix C1
APPENDIX D - ALTERNATIVE DESIGNS

In the process of designing the lifting device that would most satisfy customers based on the survey results as well as considering the characteristics of a lifting device, three designs were fabricated: the platform, the table, and the fork. After weighing the different options, the fork design was chosen as the final design for the Hydraulic Machinery Jack.

THE PLATFORM

This device is a Hydraulic Jack. The platform for which objects can be placed is built between the two long circular bars standing along the side of the hydraulic jack pump. As the jack pushes against the platform, the platform will move up along the two circular bars until it reaches the top. One flaw of this design is that if one of the bars is broken the whole jack becomes useless because the platform is dependent upon the two bars to guide it up and down. The whole device is welded together. This jack also has its limits in traveling distance, its platform cannot move all the way to the base because the jack is in the way. It has a small base and is immobile; it is also noisy and may not last long because the platform will wear out as it rubs on the two bars.
THE FORK

This lifting device uses a fork. This is a good design since the fork is short and not too wide allowing support of objects without getting bent so easily. Objects are lifted up by a jack with a nylon strap or cable attached to the fork. One end of the strap is attached to the base of the jack and the other end is attached to the fork. There is a roller on top of the jack that will help keep the strap in line as well as facilitating the movements of the strap by decreasing friction between surfaces and reduce tearing of the strap. The roller will also reduce noise volume because of smooth movements of the strap. On each side of the fork will be two wheels to guide the fork up and down the c-channel steel. This will also reduce the potential sounds during operation of the jack. Another advantage is that this jack is moveable and can be disassembled if needed for storage because the whole device has bolts and nuts that hold the major components together.
**THE TABLE**

This third device also uses the hydraulic jack. The feature of the device is quite simple. The jack is welded to the base, and then it is welded to another square frame just big enough to fit the top of the hydraulic jack. Next there are four circular bars that are welded at the four corners of the base connecting to the corners of the square frame. The table is welded to the top of the cylinder of the jack which serves as a platform for objects to be placed. One flaw in the design is if one of the parts is broken, the whole jack is useless. The whole device is welded together so one cannot disassemble it if needed. Also this jack has its limits in travel distance if you want to lift something from ground level. The device is not moveable; this jack must be physically lifted to move from point A to B.
**THE DECISION MATRIX**

<table>
<thead>
<tr>
<th>Design Criteria</th>
<th>weights Factor</th>
<th>Unit</th>
<th>Magnitude</th>
<th>Score</th>
<th>Rating</th>
<th>Magnitude</th>
<th>Score</th>
<th>Rating</th>
<th>Magnitude</th>
<th>Score</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strong frame</td>
<td>0.16</td>
<td>High/Medium/Low</td>
<td>High</td>
<td>5</td>
<td>0.79</td>
<td>High</td>
<td>5</td>
<td>0.7915</td>
<td>High</td>
<td>5</td>
<td>0.79</td>
</tr>
<tr>
<td>Capacity</td>
<td>0.16</td>
<td>High/Medium/Low</td>
<td>High</td>
<td>5</td>
<td>0.82</td>
<td>High</td>
<td>5</td>
<td>0.824</td>
<td>High</td>
<td>5</td>
<td>0.82</td>
</tr>
<tr>
<td>Stability</td>
<td>0.16</td>
<td>High/Medium/Low</td>
<td>Low</td>
<td>1</td>
<td>0.16</td>
<td>Low</td>
<td>1</td>
<td>0.1638</td>
<td>Low</td>
<td>1</td>
<td>0.16</td>
</tr>
<tr>
<td>Easy to assemble</td>
<td>0.13</td>
<td>Yes/No</td>
<td>No</td>
<td>1</td>
<td>0.07</td>
<td>yes</td>
<td>5</td>
<td>0.3287</td>
<td>No</td>
<td>1</td>
<td>0.07</td>
</tr>
<tr>
<td>Easy to repair</td>
<td>0.12</td>
<td>High/Medium/Low</td>
<td>Medium</td>
<td>3</td>
<td>0.49</td>
<td>High</td>
<td>5</td>
<td>0.8189</td>
<td>Medium</td>
<td>3</td>
<td>0.49</td>
</tr>
<tr>
<td>Easy to maneuver</td>
<td>0.07</td>
<td>Yes/No</td>
<td>No</td>
<td>1</td>
<td>0.13</td>
<td>Yes</td>
<td>5</td>
<td>0.6301</td>
<td>No</td>
<td>1</td>
<td>0.13</td>
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<td>Compact</td>
<td>0.07</td>
<td>High/Medium/Low</td>
<td>Low</td>
<td>1</td>
<td>0.07</td>
<td>Medium</td>
<td>3</td>
<td>0.2156</td>
<td>Medium</td>
<td>3</td>
<td>0.22</td>
</tr>
<tr>
<td>Light weight</td>
<td>0.06</td>
<td>High/Medium/Low</td>
<td>Medium</td>
<td>3</td>
<td>0.19</td>
<td>Low</td>
<td>1</td>
<td>0.0641</td>
<td>Medium</td>
<td>3</td>
<td>0.19</td>
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<tr>
<td>Quiet operation</td>
<td>0.04</td>
<td>High/Medium/Low</td>
<td>Medium</td>
<td>3</td>
<td>0.11</td>
<td>Medium</td>
<td>3</td>
<td>0.112</td>
<td>Low</td>
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<td>0.04</td>
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<tr>
<td>Cost</td>
<td>0.03</td>
<td>High/Medium/Low</td>
<td>Medium</td>
<td>3</td>
<td>0.10</td>
<td>Medium</td>
<td>3</td>
<td>0.099</td>
<td>Medium</td>
<td>3</td>
<td>0.10</td>
</tr>
</tbody>
</table>

From the table above is the weight decision matrix. The weight decision matrix is method of evaluate and compete for all concepts and ranking the design criteria with weighting factors and scoring the degree to which each design concept meet the criterion. The design criteria and weight factor are from the QFD. For example, the Table on strong frame has a high for Magnitude, then for score is 5, for rating is the number of score time the weight factor. Keep do calculate for every row and for all three design. After finish the calculation in each row, now on the columns of rating add them all up. Whichever one has the outcome the biggest is the winner.
APPENDIX E - GENERAL CALCULATIONS

General Calculations

The general calculations below are for the parts of the Hydraulic Machinery Jack. (Most equations used are from Machine Elements in the Mechanical Design by Robert L. Mott)

General calculations for the frames which are joined by nuts and bolts.

<table>
<thead>
<tr>
<th>Grade number</th>
<th>Bolts size</th>
<th>Tensile strength</th>
<th>Yield strength</th>
<th>Proof strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>1/4-1</td>
<td>120</td>
<td>92</td>
<td>85</td>
</tr>
<tr>
<td>6</td>
<td>&gt;1-1 1/2</td>
<td>105</td>
<td>81</td>
<td>74</td>
</tr>
<tr>
<td>7</td>
<td>1/4-1 1/2</td>
<td>133</td>
<td>115</td>
<td>105</td>
</tr>
<tr>
<td></td>
<td>1/4-1 1/2</td>
<td>150</td>
<td>130</td>
<td>120</td>
</tr>
</tbody>
</table>

\[ \sigma = \frac{F}{A} \]
\[ \sigma = \text{tensile stress} \]
\[ F = \text{loading force} \]
\[ A = \text{area where loading force is apply} \]
\[ N \ast \sigma = S_u \]
\[ N = \text{design factor of 3} \]
\[ S_u = \text{tensile strength} \]
\[ \sigma = \text{tensile stress} \]

When a force of 4,000 lb is applied to the fork, the force is transferred to the frames and the load is distributed evenly to the bolts on each of the frame. The bolt material is picked from the Machine Elements in the Mechanical Design by Robert L. Mott on page 647 Table 18-1. The material picked for this project is SAE grade 5 and the proof strength of the bolt is 85,000 psi.

The figure below is showing multiple calculations for six bolts on two row on one bracket.

\[
\sum M_A = -2000 \text{lb} \times 7.25 \text{in} + 0.75 \text{in} \times \frac{1}{3}F + 2.25 \text{in} \times \frac{2}{3}F + 3.75 \text{in} \times 1F = 0
\]
\[ F = 2636.36 \text{lb} \]
Both row with six bolts is \[ F = 5272.72 \text{lb} \]

(85,000 lb/in\(^2\)) / 3 = 5272.72 lb / (\pi D^2 / 4)
D = 0.487 in
Let use 0.5 inch diameter

The material for the bolt is SAE grade 5 with the proof strength 85,000 psi and tensile strength is 10,000 psi and yield strength is 95,000 psi. The first trial of five bolts on each side of the frame, after doing the math this result is 0.487 inch diameter. The bolt size chosen for this project is 0.5 inch diameter for all six bolts.

These calculations below are for the size of tubing of the fork.
σ = M/S
N * σ = S_y
σ = bending stress
S_y = the allow yield stress 50 * 10^3 psi.
M = magnitude of the bending moment at the section
S = section modulus
P = loading force
L = load distance of 6.2500 inch.
(50,000 lb/in^2)/3 = 2,000lb * 6.25in/(S)
S = 0.7500 in^3

Hydraulic Machinery Jack is a device with high capacity to lift heavy load and it always important to do calculations that shows the jack is capable of such stress. For this application, the material picked is steel A500 ASTM shape grade C with a 50*10^3 psi for yield strength and a picked length of load on the fork is 6.2500 inch. After obtaining the result of S, next look up Appendix A-40 from Machine Elements in the Mechanical Design by Robert L. Mott. The only one that came close to the S value for structural tubing is 2x2x1/4. These calculations below are for the diameter component of the fork.
\( \sigma = \frac{M}{S} \)

\( N \times \sigma = S_y \)

\( S_y = \) yield strength \(136 \times 10^3\) psi.

\( P = \) loading force

\( L = \) load distance of 4.2500 inch.

\( \sigma = \) bending stress

\( M = \) magnitude of the bending moment at the section

\( P = \) loading forces

\( D = \) diameter of the bar

\( S = \) section modulus

\( S = \frac{\pi D^3}{32} \)

Solve for cross section of a circular bar, horizontal component on the fork.

\( \frac{(136,000 \text{ lb/in}^2)}{3} = \frac{(2,000 \text{lb} \times 3.625 \text{in})}{S} \)

\( S = 0.160 \text{ in}^3 \)

\( 0.160 \text{ in} = \frac{\pi D^3}{32} \)
Appendix E5

D = 1.18 inch
Use 1.25 inch diameter for the bar

Based on the calculations above for the horizontal component of the fork the material selected is AISI 1137 OQT 400 from the Machine Elements in the Mechanical Design by Robert L. Mott, for this application, it is probably best to have the circle bar instead the square bar might wear out the nylon strap more quickly with its edges.

This calculation is for the bolt’s shear.

\[
\tau_{\text{max}} = \frac{4V}{3A}
\]

\[S_{\text{us}} = 0.82 \ S_u\]

\[\tau_{\text{max}} = \text{maximum shearing stress for circle}\]
\[V = \text{shear force}\]
\[A = \text{cross section area}\]
\[S = \text{the height or width of square shape}\]
\[S_{\text{us}} = \text{ultimate shear strength}\]
\[S_u = \text{shear strength}\]
\[\sum F_y = -2000 \text{ lb} + 2000 \text{ lb} = 0\]
\[\sum F_x = A - B = 0\]
\[\sum M_A = 2000 \text{ lb} * 2.7500 \text{ in} - 2000 \text{ lb} * 7.2500 \text{ in} + B * 9.5000 \text{ in} = 0\]
\[B = 947 \text{ lb}\]
\[\sum F_y = A - B = 0\]
\[\sum F_y = A - 947 \text{ lb} = 0\]
\[A = 947 \text{ lb}\]
\[S_{\text{us}} = 0.82 * 85 * 10^3 \text{ lb/in}^2 = 69700 \text{ lb/in}^2\]
\[69,700 \text{ lb/in}^2 = (4 * 947 \text{ lb}) / (3 * A)\]
\[ A = 0.0250 \text{ in}^2 \]
\[ 0.0250 \text{ in}^2 = \frac{\pi \times D^2}{4} \]
\[ D = 0.15 \text{ in} \]
Let use 1/2 inch diameter bolt

The material for the bolt is SAE grade 5 with proof strength 92,000 lb/in\(^2\), tensile strength \(S_u\) of 120,000 lb/in\(^2\) and ultimate shear strength \(S_{us}\) of 69,700 lb/in\(^2\). The diameter that works for this project is 1/2 inch diameter. The reason it is pick large diameter because people never know how heavy the objective that they are lift. Plus, it is also provided by the sponsor.

Solve for the thickness component of the fork.

\[ \sigma = \frac{M}{S} \]
\[ N \times \sigma = S_y \]
\[ \sigma = \text{bending stress} \]
\[ N = \text{design factor of 3} \]
\[ S_y = \text{the allow yield stress} 30 \times 10^3 \text{ psi.} \]
\[ M = \text{magnitude of the bending moment at the section} \]
\[ S = \text{section modulus} \]
\[ B = \text{base of rectangle shape} \]
\[ H = \text{the height of rectangle shape} \]
\[ S = B \times H^2 / 6 \text{ for rectangle shape} \]
\[ (30,000 \text{ lb/in}^2)/3 = (1,000\text{lb} \times 0.8750\text{in})/S \]
\[ S = 0.0880 \text{ in}^3 \]
\[ 0.0880\text{in}^3 = B \times (1.7500 \text{ in})^2 / 6 \]
\[ B = 0.1720 \text{ in} \]
Let use 1/2 inch thick

The material that is chosen for this part is AISI 1020 hot-rolled with yield strength of 30,000 psi and tensile strength of 55,000 psi. So the dimension of the sheet steel is 5 inch long, 1/2 inch thick and height is 1.75 inch. This one was also provided by the sponsor.
This calculation is for the bolt’s shear.

\[ \tau_{\text{max}} = \frac{4V}{3A} \]

\[ S_{\text{us}} = 0.82 \, S_{u} \]

\( \tau_{\text{max}} \) = maximum shearing stress for circle

\( V \) = shear force

\( A \) = cross section area

\( S \) = the height or width of square shape

\( S_{\text{us}} \) = ultimate shear strength

\( S_{u} \) = shear strength

\[ S_{\text{us}} = 0.82 \times 85 \times 10^3 \, \text{lb/in}^2 = 69700 \, \text{lb/in}^2 \]

\[ 69700 \, \text{lb/in}^2 = 4 \times 1000 \, \text{lb/(3*A)} \]

\[ A = 0.019 \, \text{in}^2 \]

\[ 0.019 \, \text{in}^2 = \left(\frac{\pi \times D^2}{4}\right) \]

\[ D = 0.150 \, \text{in} \]

In this case let 1/2 inch diameter

The material for the rod of the roller is SAE grade 5 and the shear stress is 69700 psi. Based on the steps above, the first step is using this equation \( S_{\text{us}} = 0.82 \, S_{u} \). Since \( S_{u} \) is given for the chosen material, solve the equation. Then apply the answer to this equation \( \tau_{\text{max}} = \frac{4V}{3A} \) to solve for \( A \) which is the area of the circle. Finally, solve for \( D \) which is the diameter of the rod, which can resist 1000 lb force. The diameters that can hold up the load from shear is 0.15 inch diameter but for real application it is hard to find such a small rod so the actual size of this rod will be 1/2 inch diameter. This one was also provided by sponsor.
The calculations below are for the base.

General calculations for the front side where bending take place.

\[ \sigma = \frac{M}{S} \]

\[ N \times \sigma = S_y \]

\( \sigma \) = bending stress

\( F \) = loading force

\( S_y \) = the allow yield stress \( 100 \times 10^3 \) psi.

\( M \) = magnitude of the bending moment at the section

Appendix E8
S = section modulus

Calculate for worse case the distance from the front of the frame goes all the way to the front with the distance of 8.5000 inch and apply on side with 2,000 on L-shape.

\[
\frac{100,000 \text{ lb/in}^2}{3} = \frac{2,000 \text{ lb} \times 20 \text{ in}}{S}
\]

\[S = 1.07 \text{ in}^3\]

Let use L-3X3X5/16

Base on the calculation for the worse case to solve for S, the only L-shape material that has the value so close is L-3X3X5/16. The material is ASTM A514 quenched and tempered with thickness less than 2½, 100,000 psi for yield strength and 115,000 psi for tensile strength. For the base will use 24X30X.117 steel sheet. There are five parts of L-shape to support the base. Two long L-shape: one on the left side and the other one on the right side to support the base from bending. The other three L-shape are in the middle: two with support under the jack and the last one for the nylon strap to tie to.

The center weight calculation in x direction.
Calculated safe distance to apply load to the fork without tipping over.
The total weight of 230
Center gravity in x direction weight
Center gravity in 11 in.
\[ x = \frac{\sum wx}{W} \]
\[ \Sigma F = -4000 \text{ lb} - 230 \text{ lb} + N_A + N_B = 0 \]
\[ N_A + N_B = 4230 \text{ lb} \quad (Equation 1) \]
\[ \Sigma M = -4000 \text{ lb}x - N_A * 11 \text{ in} + N_B * (30 \text{ in} - 11 \text{ in}) = 0 \]
\[ -4000 \text{ lb}x - N_A * 11 \text{ in} + N_B * 19 \text{ in} = 0 \quad (Equation 2) \]
Case 1 let \( N_A = 0 \) and let \( N_B = 4230 \text{ lb} \)
\[ -4000 \text{ lb}x + 4230 \text{ lb} * 19 \text{ in} = 0 \]
\[ x = 20 \text{ in} \]
Case 2 let \( N_A = 4230 \) and let \( N_B = 0 \text{ lb} \)
\[ -4000 \text{ lb}x + 4230 \text{ lb} * 11 \text{ in} = 0 \]
\[ x = 11 \text{ in} \]
L-Shape Bracket
C-channel top piece
The roller axle

the tire of the roller
The roller
The axle
The tire
The fork

Appendix F12
The hydraulic jack
The hex block
APPENDIX G - SCHEDULE

<table>
<thead>
<tr>
<th>Task</th>
<th>Winter Quarter</th>
<th>Spring Quarter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preselection of the design</td>
<td>1/7-1/11</td>
<td></td>
</tr>
<tr>
<td>Preselection of the design</td>
<td>1/14-1/18</td>
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</tr>
<tr>
<td>Proof of design</td>
<td>1/21-1/25</td>
<td></td>
</tr>
<tr>
<td>Proof of design</td>
<td>1/28-2/8</td>
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<tr>
<td>Design the device</td>
<td>2/4-2/8</td>
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<tr>
<td>Design the device</td>
<td>2/11-2/15</td>
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</tr>
<tr>
<td>General Calculation</td>
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<td>General Calculation</td>
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<td>Order materials</td>
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<td>Design freeze</td>
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<td>Oral design presentation</td>
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<tr>
<td>Prepare design report</td>
<td>3/24-3/28</td>
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<tr>
<td>Prepare design report</td>
<td>3/31-4/4</td>
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<tr>
<td>Design report due</td>
<td>4/14-4/18</td>
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<tr>
<td>Spring break</td>
<td>4/21-4/25</td>
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<td>Build frame</td>
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<tr>
<td>Build frame</td>
<td>5/2-5/6</td>
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</tr>
<tr>
<td>Build fork</td>
<td>5/9-5/13</td>
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<tr>
<td>Build fork</td>
<td>5/16-5/20</td>
<td></td>
</tr>
<tr>
<td>Build bracket</td>
<td>5/23-5/27</td>
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</tr>
<tr>
<td>Build bracket</td>
<td>5/30-6/4</td>
<td></td>
</tr>
<tr>
<td>Build base</td>
<td>6/9-6/13</td>
<td></td>
</tr>
<tr>
<td>Oral presentation</td>
<td>11-March</td>
<td></td>
</tr>
<tr>
<td>Prepare design report</td>
<td>22-May</td>
<td></td>
</tr>
<tr>
<td>Design report due</td>
<td>28-May</td>
<td></td>
</tr>
<tr>
<td>Oral presentation</td>
<td>11-Jun</td>
<td></td>
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</tbody>
</table>
## APPENDIX H - BUDGET

<table>
<thead>
<tr>
<th></th>
<th>Estimate schedule</th>
<th>Actual schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-shape/L-shape/square tubing/steel sheet</td>
<td>$135.31</td>
<td>Frame</td>
</tr>
<tr>
<td>Hydraulic jack</td>
<td>provided</td>
<td>Lift mechanism</td>
</tr>
<tr>
<td>Nuts/bolts/Washers</td>
<td>$24.21</td>
<td>Load platform</td>
</tr>
<tr>
<td>Nylon strap</td>
<td>provided</td>
<td>Misc service</td>
</tr>
<tr>
<td>base sheet</td>
<td>provided</td>
<td>Nuts/bolts/Washers</td>
</tr>
<tr>
<td>roller</td>
<td>provided</td>
<td>Cable/Nylon strap</td>
</tr>
<tr>
<td>fork wheel</td>
<td>provided raw stock</td>
<td>Total</td>
</tr>
<tr>
<td>brush paint/ paint brush</td>
<td>$10.34</td>
<td></td>
</tr>
<tr>
<td>chains</td>
<td>$21.24</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>$191.10</td>
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