Design and Cost Analysis of an ATV Freestyle Motocross Ramp

By

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California Polytechnic State University
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SIGNATURE PAGE

TITLE : Design & Cost Analysis of an ATV Freestyle Motocross Ramp

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DATE SUBMITTED : June 1, 2012

Dr. Shaun F. Kelly
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Department Head
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ABSTRACT

This project encompasses the final design of an improved ATV freestyle motocross ramp. The project parameters were decided on by Thaddeus Pedro. This evaluation includes an analysis of the final improved design. This report does not include any construction procedures of any kind.

Research for the project encompasses the cultural history of the freestyle motocross sport and variations of the freestyle motocross ramp. Further research includes the analysis of an existing ramp used as a basis for improvement for the new ramp. The theoretical results indicate a significant improvement in structural weight reduction and reduced material cost.
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INTRODUCTION

The sport of freestyle motocross (FMX) riding has grown considerably in the last ten years with ATV riders and dirt bike riders alike. More riders get into the sport every year and train hard in hopes of catching the attention of sponsors or one of the many professional freestyle teams on tour. Many of these riders train in their own private compounds but most don’t achieve the required skill level due to inconsistent or inadequate practice, or injury associated with the former. In order to progress in the sport, one needs to practice to make perfect; in order to make perfect practice, one needs consistency. The best way to achieve consistency is with a freestyle motocross ramp.

Predictability is the most important part of freestyle motocross. The rider needs to be confident in letting go of the bike in air and know how it will react. As opposed to take-off jumps made of sand or dirt which wear out and can change a rider’s trajectory only after a few runs, a ramp provides the best means of achieving consistent and predictable take-offs, flight, and hang-time characteristics. It is important that riders new to freestyle motocross start small and work their way up. This is done by placing the ramp close to the landing and initially jumping distances as small as 10 feet. As the rider increases their skill and becomes more comfortable, the ramp can be moved farther back from the landing in incremental distances to create a bigger jump. The increase in distance allows the rider to jump higher and farther with more hang-time to pull off more difficult tricks.

However, a ramp is not a cheap investment. Some ramps are made of wood, but most are made of steel. Steel fabricated ramps range in cost from $2000 to $4000. Other custom or purpose built ramps can cost over $5000. Most ramps are also fabricated as one section which can be difficult to move around. Other ramps are fabricated in 2 or 3 sections that can be folded up for transport but are still just as heavy and difficult to move. Most ramps require heavy equipment like a tractor or loader in order to be moved. Cost, weight, and equipment are factors that can make or break a rider’s quest to progress in freestyle motocross, especially if they are beginners and/or on a budget.

There are many different ramp designs with various curves but most conform to one particular style of assembly. Most ramps are fabricated using 2” x 2” x 1/8” HSS square tubing for the frame and 16 ga. sheet metal with #9 raised expanded metal for the ramp surface. The average ramp is approximately 8 feet tall and 20 feet long with a launch angle of 40-45 degrees. This allows the rider to reach heights up to 30 feet and fly distances up to 80 feet while performing at the professional level.

After researching various designs, an idea was created to find the best combination of cost, weight, portability and performance from an improved concept design of a freestyle motocross ramp. Figure 1 illustrates the geometry of the proposed ramp design.
The objective of this senior project was to design and evaluate the improved concept design of a Freestyle Motocross ramp with the following constraints in mind:

1. The ramp must be designed to provide the same level of utility of an existing manufactured ramp.
2. The ramp must be designed to meet the same safety standards (ex. Tipping).
3. The ramp must be designed within the same size dimensions: 8 feet tall x 20 feet long x 6 feet wide.
4. The ramp can be made of different materials providing they satisfy the previous three parameters.
5. The ramp must be of a more portable-friendly design for the user.
6. The ramp must be less than or equal to the cost of an existing manufactured ramp.
LITERATURE REVIEW

Freestyle evolved from Free-riding which is regarded as the original form of Freestyle. Traditionally done on public land, riders would find natural terrain jumps and attempt to execute their tricks on. It generally has no structure and in many ways requires more skill and mental ability than Freestyle Motocross. Freestyle Motocross, also known as FMX, is a variation of the original Motocross (MX) sport. Originally in Motocross, a number of riders on dirt bikes or ATVs, race around a dirt track that consists of varying technical jumps and obstacles. The main objective for motocross, just like any other racing event, is to finish first with a fast time also while trying not to crash. This type of display of the riders’ skills and abilities is what impresses the audience. Freestyle Motocross, however, has a different approach to its objective. In Freestyle, the most stylish and daring display of the rider’s abilities is what impresses the audience. There are two main types of Freestyle events. They are Freestyle Motocross and Big Air, also known as Best Trick. Freestyle Motocross is the original form of the sport. Each rider competes individually on a course that encompasses about two acres of track area. The course consists of multiple jumps varying in size and trajectory. The rider has two minutes complete their run on the course. A panel of judges scores the rider on trick difficulty, trick variation, trick execution, and flow around the course. The score is based on a 100 point scale and the highest score wins. In Big Air each rider gets two runs at a single jump usually at a gap set at 75 feet from a ramp. The judges score the rider’s trick based on difficulty, originality, and execution. The score is also based on a 100 point scale and the top score wins (Wikipedia, 2012).

A freestyle motocross ramp is a critical component in being successful in the sport. A ramp provides the means of consistency when executing or attempting new tricks. However, the problem with existing solutions is that every ramp constructed is different from one another even though they are seemingly built to the same specifications. There are well designed ramps and poorly designed ramps. Some are made of steel and some are made of wood. Each ramp has a different feel to it when jumping and riders will go through several ramps until they find one that they like. As mentioned before, the sport of freestyle generally has no structure, which explains why every ramp is constructed a different way. The average ramp is built to provide a launch angle between 40 and 45 degrees, and is 8 feet tall, 20 feet long, and 4 feet wide; 4 feet is an acceptable width for dirt bikes, ATVs require at least 6 feet of width. Although every ramp aims for this certain launch pattern and particular type of assembly, the ramps are still different from one another (Fargher, 2011). It is somewhat ironic in the sense that the key element that provides consistency is not consistent within itself. Another problem is that materials and fabrication can get expensive, which is why most new riders are stopped in their quest at this point when seeking to progress in the sport. Another problem is that ramps are heavy. The average ramp weighs approximately 1300 to 1500 lbs. A ramp is not an easy thing to move around unless heavy equipment like a loader, tractor, or forklift is used. Some ramps are fabricated into trailers with their own set of wheels that can be moved around by a truck, but these ramps are even heavier which is why they require a truck. Sometimes space may be limited and the use of a tow vehicle may not be feasible. Other ramps are equipped with a simple bolt-on dolly wheel system that can be moved by a couple of people. However, the problem with this is that the wheel system is not often strong enough and it breaks. A close friend of mine has his own freestyle motocross ramp with this particular set-up. The wheel
mounts broke away from the main frame while moving the ramp into position. This occurred only on the second day he had the ramp in his possession.

As previously mentioned, the sport of freestyle generally has no structure. Its elements are based off the feel for things. The only modifications or improvements made within the sport stem from the input of top level professional riders. With that said, there are no official laws or regulations for the sport. Accepted guidelines do exist for ramp and course construction and safety standards regarding rider safety, but nothing that really governs the sport itself. When it comes to constructing a freestyle ramp, the most common method to attain a sound ramp structure is to fabricate it out of steel tubing. The most common materials used in the fabrication of freestyle ramps are: 2” x 2” x 1/8” wall steel square tubing, 1” x 1” x 1/8” wall steel square tubing, 16ga sheet steel, and #9 raised expanded metal (Distler). Other optional materials include ¼” or 3/8” bolts for fastening a hinge if the ramp is designed to fold up for storage or transport. Additional accessories include wheels for mobility. The finished product results in a durable ramp that can withstand approximately 40,000 hits or jumps a year without maintenance. It is essential that the ramp curve be an elliptical radius, not a constant radius (Distler).
PROCEDURES AND METHODS

Measurement Procedure

In order to make design improvements, a visitation to an existing freestyle ramp was conducted. During the visitation, an analysis of the ramp’s frame structure provided a basis for improvement. The existing ramp served as a template to make further improvements and modifications for the new design. Basic measurement techniques involving a standard tape measure were used to measure the lengths of all the framework components of the existing ramp. Simple sketch drafting drawings were used as a starting point for the new design. Figures 2 and 3 show the measurements taken of the original ramp.

Figure 2. Side profile view of the original ramp with dimensions.
The primary objective during the design phase was to design a new freestyle motocross ramp that featured weight reduction, maintained or improved strength, improved mobility, and lower cost. The design in mind would cater to new riders starting out or trying to progress in freestyle who are also on a budget. The new design would also be lightweight enough that only one or two people would be required to move it, and would not sacrifice weight for strength. The structural specifications of the new ramp would still adhere to the accepted 8 feet tall x 20 feet long frame. In this case, the ramp would be designed to accommodate specifically ATVs, so the overall width would be 6 feet. A minor change in the design attributes to the new launch angle. The existing ramp has a launch angle of $40^\circ$ which allows the rider to reach horizontal distances up to 80 feet. The new launch angle will be $42.5^\circ$ which will limit the horizontal distance to 65 feet; the rider’s vertical height limit will remain the same. The ramp would also be designed to fold in half. Due to the design’s proposed lighter weight, a safety issue that would possibly arise would be tipping. The new ramp’s design would account for tipping forces.
The new design would also incorporate a more durable system of wheels to improve portability. This new wheel system would feature a series of trailer jacks with wheels. This way, the lifting and motility could be achieved by implementing one type of device. The jacks would be placed on four corners of the base of ramp’s frame perimeter. Two would be placed toward the front or “lip” and two would be placed midway down the frame at the point where the ramp folds. This would allow the ramp’s tail end to be folded up and then the entire ramp itself could be lifted and moved on the wheel jacks. When the desired adjustment is made, the ramp could then be lowered back down on the ground to sit on its frame.

**Material Selection**

It was decided that the new ramp would be design with similar conformity to the existing ramp. The existing ramp materials consist of:

- Steel tubing (HSS), steel sheet, expanded steel sheet.
  - 2x2 HSS ST, 1x1 HSS ST, 16ga steel sheet, #9 expanded steel sheet

The materials selected to use for new ramp consist of:

- 2x1 HSS RT, 1x1 HSS ST, 16ga steel sheet, #9 expanded steel sheet.

The major difference in material selection was the choice of steel tubing that would be used to fabricate the side frame. Theoretically, with the new tubing being only half the width of the original, major weight savings would result. Another critical factor that would increased weight savings would be the amount of sheet steel used. On the original ramp, the entire curve surface was covered with sheet steel. For the new design, sheet steel would be used in strips that would only cover portions of the cross members where the tires of the ATV would roll. Expanded metal would still cover the entire surface for traction and provided rigidity for the curve surface.
Before any major design procedures could begin, the existing ramp must first be analyzed to determine its current weight. After measurements were taken, a pound per foot calculation was used for all materials to determine its weight. Once a total weight was found, which was accurate to the claimed weight of the ramp at 1300 lb (Distler), design improvements could then be made. The following calculations and equations show further data on the material selection process. Calculations include total feet of materials, total weight of materials, stress calculations of loads placed on frame members and other statics equations showing the strength of materials.

**Existing Ramp Data:**

Total feet of 2”x2”x1/8” square tubing = 168.33 feet  
Total feet of 1”x1”x1/8” square tubing = 195.785 feet  
Total square feet of 16ga sheet steel = 136.875 ft²  
Total square feet of #9 raised expanded metal = 136.875 ft²

Total weight of 2”x2”x1/8” square tubing = 168.33 feet x 3.05 lb/ft (AISC) = **513.4 lb**  
Total weight of 1”x1”x1/8” square tubing = 195.785 feet x 1.436 lb/ft (AISC) = **281.15 lb**  
Total weight of 16ga sheet steel = 136.875 ft² x 2.5 lb/ft² = **342.2 lb**  
Total weight of #9 raised expanded metal = 136.875 ft² x 1.2 lb/ft² = **164.25 lb**  
**TOTAL RAMP WEIGHT = 1301 lb**

**New Ramp Data:**

Total feet of 2”x1”x1/8” square tubing = 173.5 feet  
Total feet of 1”x1”x1/8” square tubing = 93.3 feet  
Total square feet of 16ga sheet steel = 88 ft²  
Total square feet of #9 raised expanded metal = 132 ft²

Total weight of 2”x1”x1/8” square tubing = 173.5 feet x 2.2 lb/ft (AISC) = **381.7 lb**  
Total weight of 1”x1”x1/8” square tubing = 93.3 feet x 1.436 lb/ft (AISC) = **134 lb**  
Total weight of 16ga sheet steel = 88 ft² x 2.5 lb/ft² = **220 lb**  
Total weight of #9 raised expanded metal = 132 ft² x 1.2 lb/ft² = **158.4 lb**  
**TOTAL NEW RAMP WEIGHT = 894 lb**

ATV load on ramp = ATV weight ≈ 400 lb + Rider weight ≈ 150 lb = **550 lb**

**Beam diagram # 7 (AISC)**

![Beam diagram](https://via.placeholder.com/150)

550 lb  
Front tires = 275 lb  
Rear tires = 275 lb

\[ R = \frac{P}{2} \Rightarrow 550 \text{ lb/2} = 275 \text{ lb @ front and rear tires} \]
Beam diagram # 7 (AISC)

![Beam diagram # 7](image)

Left tire = 275 lb
Right tire = 275 lb

R = P/2 => 275 lb/2 = 137.5 lb @ each tire

Beam diagram # 9 (AISC)

![Beam diagram # 9](image)

M = Pa => 137.5 lb x 16” = 2200 in/lb

S = M/τ = 2200 in/lb = 0.078 in³ required for crossmember
28000 PSI
(28KSI is the yield stress for HSS tubing)

Section modulus calculation for 1”x1”x1/8” square tubing crossmember:

Hollow rectangle (AISC) \( S = \frac{bd^3 - b_1d_1^3}{6d} = (1” \times 1“^3 - 0.75” \times 0.75“^3)/6 \times 1” = 0.1139 \text{ in}^3 \)

\( S = 0.1139 \text{ in}^3 > 0.078 \text{ in}^3 \)

Section modulus calculation for 24” wide strip of 16ga sheet steel used for tire coverage:

\( S = \frac{bd_1}{6} = (24” \times 0.0625 \text{ in}^2)/6 = 0.0156 \text{ in}^3 \)

Combine section modulus of sheet steel with crossmember:
Total \( S = 0.1139 \text{ in}^3 + 0.0156 \text{ in}^3 = 0.129 \text{ in}^3 > 0.078 \text{ in}^3 \)

Maximum vertical load for 2”x1”x1/8” square tubing columns:
Note: rotation and translation fixed, \( K = 0.5, r = 0.39, l = 96” \) for longest column
\( A = 0.608 \text{ in}^2 \)

\( KI/r = 123.07 \Rightarrow 124 \Rightarrow 9.78 \text{ KSI} = 9780 \text{ PSI} \)

\( P = A \times \tau = 0.608 \text{ in}^2 \times 9780 \text{ PSI} = 5946 \text{ lb} > 550 \text{ lb} \)

These calculations reveal that the strength of the frame is more than capable of supporting the load of the ATV and rider on the ramp.
Cost Analysis

The total material cost for the existing ramp is quoted at $2,500.00 (Distler). Since the total amount of feet and square feet of material calculated for the new ramp is a cut list total, the numbers must be rounded up to whole values to order material. The list of materials to order for the new ramp is listed in the bill of materials below (Metals Depot).

Total feet of 2”x1”x1/8” square tubing = 173.5 feet => order 180 feet
Total feet of 1”x1”x1/8” square tubing = 93.3 feet => order 100 feet
Total square feet of 16ga sheet steel = 88 ft² = order 3(4’x 8’ sheets) = 96 ft²
Total square feet of #9 raised expanded metal = 132 ft² => order 9(2’ x 8’ strips) = 144 ft²

The total cost for the new ramp is $1,373.10. In comparison to an original price of $2,500.00, this new price results in approximately a 45% price reduction.

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<td>2X1X11 GA (.120 wall) A513 Steel Structural Rectangle Tube</td>
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<td>3</td>
<td>16 GA (.060 thick) Steel Sheet Hot Rolled Steel Sheet</td>
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<td>9</td>
<td>3/4 inch Diamond x 9 GA Steel Expanded Metal - Raised</td>
<td>2 x 8 Ft.</td>
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<td>$540.00</td>
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Sub-Total: $1,373.40
Shipping: $0.00
Total: $1,373.40

Figure 5. Bill of materials for improved ramp design (Metals Depot).
In order to maintain portability of the new ramp design, a system of trailer jockey jacks would be used to lift the ramp off the ground and move into position. With the possibility of wheels breaking off as in the case of the original ramp, a set of higher rated jack wheel will be used. The jacks will placed in the following locations as shown below in Figure 7. This placement of four jacks will ensure a safety factor of $5 : 1 = ((1200 \text{lb} \times 4 \text{ jacks}) / 890 \text{ lb ramp})$. Figure 6 shows the selected jack to be used for the new ramp. The total price for the jacks will be $168.80. When added to the bill of materials the new total price for the new ramp is $1,541.20.

Figure 6. A swivel jockey jack selected to use to ensure portability of the new ramp design.

Figure 7. Side profile view of new ramp design with jack placement.
RESULTS

The final results indicate that the new ramp design shows a total weight reduction of **406 lb** which equates to a **31.53%** decrease in total weight. If the jockey jacks are mounted to the new ramp, then the total adjusted weight for the new ramp would be (894 lb + (14 lb/jack x 4jacks)) = **950 lb**. This would equate to a **27%** decrease in total weight. In addition, with each jack priced at $41.95, the final bill of materials would be $1,373.40 + ($41.95 x 4 jacks) = $**1,541.20**. The new adjusted reduced price would be decreased by **38.4%**.

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<td>Portability (%)</td>
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Table 1. Summary of Results
DISCUSSION

A challenging aspect of this senior project was the gathering of preliminary informational materials. There is not a lot known about the sport of freestyle motocross in terms of tangible scientific data. This industry goes by the “feel” for things as what the sport of freestyle is all about. As such, there is technically no wrong way to do something. There is always a better way, rather a more “stylish” way, but the only wrong way to do something in the sport is really, in essence, to crash and attain bodily injury. Fortunately, for this senior project there was no crashing involved. No persons were hurt in gathering of research.

The results of this senior project are purely theoretical. Just as in the sport itself, the rider can only speculate so much about attempting the jump before second guessing himself. The improved ramp design in this project will theoretically hold up to the abuse it would see in the field. The calculated data proves the frame structure is strong enough and more so, is similarly designed with common materials to that of an existing ramp that does indeed hold up to real world abuse. The only fault or failure of this design would result from depending skill level of the fabricator. Since most ramps are “backyard” built, it would be unreasonable to assume that all ramps are constructed the exact same way.

The tangible results that are undeniable are the reductions in price and weight. A 27% reduction in weight and a 38.4% reduction in costs are significant improvements over the existing ramp that was analyzed. It is safe to say that after researching this topic that the project parameters were met. This new design maintains its structural strength without compromising its performance all while being made of different material variants. Just like the existing ramp, the design is also drawn to the same size specifications as an industry accepted freestyle ramp. Finally, and most successfully of all, the new ramp greatly improves upon portability with its system of jockey jacks, and its significant reduction in overall price meets the demands of a rider on a budget.
RECOMMENDATIONS

A recommendation for this senior project would be to analyze the use of different materials such as wood. To take this recommendation even further, experiment with vastly different materials like aluminum, chromoly, or even titanium just to see what ranges of strength each material would result in. However, it was not possible in this senior project to analyze such materials due to the fact that the American Institute of Steel Construction Manual only focuses on “steel.” Therefore, the selection of materials was limited to only different variants of steel in order to draw sound conclusions. In speculation of researching these recommended materials, it could be said that all of these metals would unfortunately be much more expensive than steel. This would ultimately defeat the purpose of the design’s cost-effectiveness only to theoretically see small increases in strength and reductions in weight.

Another recommendation would be to further develop the ramp’s system of portability. With more time and resources, a much more sophisticated motility system could be designed. For the current parameters, this design is more than sufficient for the rider looking for a good deal. The last recommendation for this senior project would be to actually fabricate the new ramp design. It would be very interesting and rewarding to see how the real finished product would actually look and how it would perform in the field. However, it may well prove difficult to find an experienced fabricator familiar with constructing freestyle ramps in order to avoid making inexperienced mistakes during construction. Mistakes as such would result in an increase in material cost if fabrication errors are made, and as the sport of freestyle motocross clearly implies: proceed at your own risk.
REFERENCES


APPENDIXES
APPENDIX A

Project Contract
The project will involve the application of design technologies. The project will involve business/management skills in the areas of cost and value analysis for the project. Quantitative problem solving will include cost analysis and statics calculations.

**Capstone Project Experience** - The ASM senior project must incorporate knowledge and skills acquired in earlier coursework (Major, Support and/or GE courses).

- 133 Engineering Graphics, 151 Auto CAD, 343/344 Mechanical and Fabrications Systems, 418/419 Ag Systems Management, Technical Writing

**ASM Approach** - Agricultural Systems Management involves the development of solutions to technological, business or management problems associated with agricultural or related industries. A systems approach, interdisciplinary experience, and agricultural training in specialized areas are common features of this type of problem solving. (insert N/A for any area not applicable to this project)

- The project involves improving upon a technical design using a systematic...
The approach to provide a more cost-effective product at the same value.

<table>
<thead>
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<th>Interdisciplinary features</th>
<th>The project touches on aspects of mechanical and fabrication systems.</th>
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<td>Specialized agricultural</td>
<td>The project applies specialized knowledge in mechanical design.</td>
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<tr>
<td>knowledge</td>
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**Project Parameters**

1. The ramp must be designed to provide the same level of utility of an existing manufactured ramp.
2. The ramp must be designed to meet the same safety standards (ex. Tipping).
3. The ramp must be designed within the same size dimensions: 8 feet tall x 20 feet long x 6 feet wide.
4. The ramp can be made of different materials providing they satisfy the previous three parameters.
5. The ramp must be of a more portable-friendly design for the user.
6. The ramp must be less than or equal to the cost of an existing manufactured ramp.

**List of Tasks and Time Estimate**

<table>
<thead>
<tr>
<th>TASK</th>
<th>Hours</th>
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<tbody>
<tr>
<td>Research in library on traditional ramp designs to assess a foundation for comparison.</td>
<td>30</td>
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<tr>
<td>Visitation to an existing ramp to analyze the design and construction.</td>
<td>6</td>
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<tr>
<td>Consultation with a FMX ramp manufacturer.</td>
<td>4</td>
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<tr>
<td>Prepare a working drawing of improved design.</td>
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<tr>
<td>Materials assessment.</td>
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<td>Modification to design.</td>
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<td>Cost analysis of improved design vs. existing.</td>
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<td>Preparation of written report.</td>
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TOTAL 150

**Financial Responsibility**

Preliminary estimate of project costs: $__________________________

Finances approved by (signature of Project Sponsor): __________________________

**Final Report Due:**

**Number of Copies:**

**Approval Signatures**

<table>
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<tr>
<td>Student</td>
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<tr>
<td>Proj. Supervisor</td>
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<td>Department Head</td>
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