Making Sustainability Palletable
ArcelorMittal USA

The Woodchippers
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Table of Contents

Abstract ........................................................................................................................................... 2
Problem Statement ............................................................................................................................. 3
Definition of Sustainability ................................................................................................................. 4
Background ......................................................................................................................................... 5
Customer Needs ............................................................................................................................... 6
Concept Generation ........................................................................................................................... 8
Concept Selection ............................................................................................................................. 9
Design Review .................................................................................................................................... 11
Model of Process .............................................................................................................................. 13
Systems Diagram ............................................................................................................................. 14
Cost and Feasibility Analysis ............................................................................................................ 15
Life Cycle Analysis ............................................................................................................................ 16
Conclusion .......................................................................................................................................... 17
References .......................................................................................................................................... 18
Acknowledgements ........................................................................................................................... 19
For this project, we were tasked by ArcelorMittal with tackling the problem of reducing their lumber waste and ecological footprint while increasing overall sustainability. We had to find a way to convert wooden pallets and rail cars into a reusable product. After brainstorming, careful consideration, and thorough process analysis we came up with a method that fit the customer needs. We chose to put the lumber through an industrial wood chipper (1000 Tub Grinder) so that the nails and staples wouldn’t affect the blades as well as it has the capability to separate the metal from the wood and run off of electricity. The end result is a product that can be repurposed and sold to make a profit.

We found that this method would involve a fairly large initial payment but the wood chipper would end up paying for itself in a little under three years. We believe that this option would be feasible because after ArcelorMittal breaks even they would then be making a profit of approximately $36,000 a year just from the wood chips. The method is also sustainable and produces low emission all while meeting the customer needs.
Problem Statement

ArcelorMittal would like to reduce the volume of wasted lumber, which is used to transport raw materials to the factory for processing, in order to reduce the company’s ecological footprint and increase overall sustainability.

The wasted material not only impacts the company’s productivity and revenue, but also adversely damages the earth by increasing the ecological footprint. After receiving and processing critical raw materials required in the manufacturing of ArcelorMittal steel, the company is left with excessive quantities of wooden pallets and railcar supports. At this point in time, these excess materials are discarded instead of being reused and recycled. Much of the lumber is wasted because of the presence of nails and screws. This problem should be given utmost importance and be fixed as soon as possible to make the plant an efficient place to produce. The excess wood is currently either given free of charge to plant employees for personal use or sent to landfills for disposal. Fixing this problem would allow perfectly good wood to be reused in a multitude of different ways.

To achieve this goal, we will optimize the process of nail removal in order to maximize efficiency during the deconstruction of the crates and pallets. We will investigate eco-friendly methods of wood disposal in hopes to discover a better disposal alternative.
Definition of Sustainability

As defined by ArcelorMittal, sustainability means “striving to develop a cleaner steelmaking process.” Their operating philosophy is to “produce safe, sustainable steel.” As a group we have created our own definition of sustainability and used that definition to lead us in our problem solving strategies. To us sustainability means something that is long lasting, and able to produce the same results multiple times. We strive for our solutions to be environmentally friendly, safe and to use our resources in the most effective manner.
Background

Wooden Pallets are usually disassembled because it is easier to handle the wooden boards when they are separated from each other. Our initial approach for recycling the wooden pallets was to disassemble them, remove the nails and then sell or reuse the wood. Patent research showed many devices that were used to pry the wooden pallets apart. There is a product that uses band saws to cut along the connection of the planks of wood [1]. The saw would cut through the nails in the wood, while leaving the planks intact. The planks however would still have the nails imbedded inside of them which is not ideal for our solution. We also did research on how to easily remove nails from pallets. The ideas we found included a type of magnet [2] or an electric drill [3] that would remove the wood immediately surrounding the nail making it easier to pry it out. The last idea that we researched was the recycling of wooden pallets and many people recommended the shredding of the pallets to create wood chips however there were many complaints about the nails dulling the blades of the shredders or jamming the machine.
Customer Needs

In order to start organizing our project requirements into a statistical manner, our group decided to compose an AHP matrix. An AHP (analytical hierarchy process) matrix is used to determine what elements of a product’s design is most crucial to the success of the device. In other words, it is a tool that is used to help rank the importance of different elements of a project by comparing each element to one another. Given the constraints provided by ArcelorMittal, our group compiled a list of 8 necessities that we believed to best fit their requirements. In no specific order, our initial list of needs was as follows: (1) cost effective, (2) time effective, (3) non labor intensive, (4) simplicity of use, (5) safe, (6) reliable, (7) durable, and (8) profitable. Our AHP matrix is displayed in figure 1.1 below.

**Figure 1 - AHP Matrix**

<table>
<thead>
<tr>
<th></th>
<th>Cost effective</th>
<th>Time effective</th>
<th>Non-labor intensive</th>
<th>Simplicity of use</th>
<th>Safe</th>
<th>Reliable</th>
<th>Durable</th>
<th>Profitable</th>
<th>Total</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost effective</td>
<td>1</td>
<td>.5</td>
<td>1</td>
<td>2</td>
<td>.33</td>
<td>.5</td>
<td>.33</td>
<td>1</td>
<td>6.66</td>
<td>.097</td>
</tr>
<tr>
<td>Time effective</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>.5</td>
<td>.33</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>9.83</td>
<td>.153</td>
</tr>
<tr>
<td>Non-labor intensive</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>.5</td>
<td>.66</td>
<td>.5</td>
<td>.5</td>
<td>8.16</td>
<td>.119</td>
</tr>
<tr>
<td>Simplicity of use</td>
<td>.5</td>
<td>2</td>
<td>.33</td>
<td>1</td>
<td>.5</td>
<td>.33</td>
<td>.5</td>
<td>2</td>
<td>7.16</td>
<td>.105</td>
</tr>
<tr>
<td>Safe</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>.234</td>
</tr>
<tr>
<td>Reliable</td>
<td>2</td>
<td>.5</td>
<td>1.5</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>.176</td>
</tr>
<tr>
<td>Durable</td>
<td>3</td>
<td>.5</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>.183</td>
</tr>
<tr>
<td>Profitable</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>.5</td>
<td>.33</td>
<td>.5</td>
<td>.5</td>
<td>1</td>
<td>6.83</td>
<td>.100</td>
</tr>
</tbody>
</table>
After composing the matrix, it was very clear as to which elements of the project needed to be focused on during the design of our device. Shown in the last column of figure 1.1 are the weighted equivalents for each of the different elements. These weighted figures allowed us to rank the 8 elements in a very specific and purposeful way. Our elements are organized from most important to least important in the list below.

1. safe
2. durable
3. reliability
4. time effective
5. non-labor intensive
6. simplicity (ease of use)
7. profitable
8. cost effective

As shown by the results of the AHP matrix, the three most important criteria are safety, profitability, and reliability. This is logical because almost all of the other requirements act as a subsidiary to these three. If the project is designed to be safe, most likely it will be non-labor intensive and relatively simple to use. Similarly, durability will reduce the maintenance required to upkeep the machine, and therefore maximise cost effectiveness and profitability. All of this considered, the AHP acted as a successful means to identify a specific order of design constraints.
Concept Generation

Our initial idea for recycling the pallets was to remove the nails and then recycle the wood. The process of removing the nails however would most likely damage the wood by either splintering it or making it weaker because of the great force needed to pull the nails out. This would bring down the value of the wood, and would not be beneficial for us since we planned on re-using or selling the wood.

We then thought of the idea of just cutting the nails down so that they would be flat along the wood. However, the quality and worth of the wood would not be high because nails would still be imbedded in so reselling the wood would be hard.

We then researched how pallets are disposed of when they are done being used by other companies. We looked at wood shredders but found that if a pallet was to be put into the machine, the nails in the pallets would dull the blades of the shredder very quickly. The shredding of the pallets would allow for a new final product of wood chips which could be sold.
Concept Selection

We put all three of our concept ideas in a matrix and we ranked them against our customer needs. Our matrix can be seen below. We ranked each of our ideas against the customer needs of ArcelorMittal, on a scale of one to five, five meaning that the design meets the requirement very well and one meaning that the design fails to meet the requirement. These numbers were then added up and that total is the leftmost number in the total column. We then calculated the total of each design using the rankings for each of the customer needs. We took the score of the design features and multiplied them by the rankings of each of the customer needs (which is the number shown in the parentheses underneath the customer needs) and added them together to get the total which is shown in the bottom right of the total column. The greater the number of the total the better the design met the design requirements and customer needs. After all of the calculations, is it shown that the chipping of the wood and selling it as a final product met the customer needs most effectively, therefore we selected this as our proposed solution.

Many pallets, after they are used, are not in good condition. Most of them are worn and weak. The wood planks would then not be good for reusing or selling. So shredding the wood would create a new final product that would be sellable, and create a new profit for ArcelorMittal.

For our solution to be profitable to ArcelorMittal the shredder would need to be able to cut through the nails because disassembling and removing the nails from the wood first would be too labor intensive and time consuming. It would also be very costly to have to often replace the blades of the machine. We needed a machine that will be able to shred the intact pallets and be able to cut through the nails without wearing over time. Tub grinders do just that, and we found a grinder called the Morbark 1000. This Tub Grinder can shred through the wood and nails without damaging or dulling the blades over time. The model can also work fully on electric power. We will then have the shredded wood separated from the shredded bits of nails. The shredded wood will then be shipped off to be bagged and sold as a final product, and the nail bits recycles.
<table>
<thead>
<tr>
<th>Design</th>
<th>cost effective (1)</th>
<th>time effective (5)</th>
<th>non-labor intensive (4)</th>
<th>simplicity of use (3)</th>
<th>safe (8)</th>
<th>reliable (6)</th>
<th>durable (7)</th>
<th>profitable (2)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design 1:</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cut nails and</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>26</td>
</tr>
<tr>
<td>leave in wood</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
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<td>Design 2:</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Remove nails</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>25</td>
</tr>
<tr>
<td>manually /</td>
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<tr>
<td>mechanically</td>
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<td></td>
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<td>Design 3:</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chip wood and</td>
<td>4</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>33</td>
</tr>
<tr>
<td>sell as new</td>
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<td></td>
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<td></td>
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</tbody>
</table>

**Total:** 129, 116, 149
Design Review

Our design review concluded that the other group fully supported our idea and did not provide a substantial amount of new recommendations. Instead, our two groups discussed different facets of the proposed process and located aspects of our final design that seemed lacking. After the peer review had ended, our group reviewed the provided responses and developed a few specific action items that we felt it necessary to address. These action items consisted of facets of our design proposal that were lacking in depth or seemingly needed improvement.

Rather than offering re-design propositions to our business model, the peer review acted to justify the legitimacy of our solution. Both of our groups proposed a very similar solution to the pallet/railcar problem, so by discussing our concepts we were able to help benefit both our teams. The discussion with the other group reassured our confidence in the final design proposition, which is outlined, in brief, below.

Our solution begins with the purchase of a Tub Grinder. A Tub Grinder is a machine that has the capability of chipping fully assembled wooden pallets. After the pallet is placed in the top bin of the machine by a laborer, a strong set of metal “teeth” located at the base of the main bucket grids the pallet wood and nails into wood chips and nail bits. This is the full extent to which workers must interact with the device, so it completely eliminates the time/labor intensive work involved with manually disassembling pallets. The wood chips and nail shards are then sent down a conveyor belt and run under a strong magnet. From above, the magnet will be able to separate all of the nail bits from the remaining wood chips and discard them in a separate container located next to the belt. The nail bits can then be recycled and used by ArcelorMittal in the process of steelmaking and the wood chips can be sold to other distributors.

Before the design review, our group had proposed that ArcelorMittal sell the excess wood chips to businesses that burn wood as a source of biofuel. There are many different industries that rely heavily on wood as a biofuel to operate their internal systems, and so this seemed like the best option. After conducting the peer review though, we realized that there is no need to identify a specific location that the chips should be sent because there are many
industries that are interested in purchasing the wood chips. As a group, we identified three separate options as to where the wood chips should be sold: biofuel companies, landscaping industries, and various nature trail organizations. Selling it to these companies would not only make revenue for ArcelorMittal, but also help lower the eco footprint of their company. For example, by selling the wood chippings to nature centers and nature parks, ArcelorMittal would contribute to the construction of foot trails. The pallet chips would act to suppress vegetation growth, raise the tread in muddy areas, and overall promote the preservation of the environment. This would allow ArcelorMittal to simultaneously profit while promoting the safety of the environment.
Model of process

Because our solution is formatted mostly as a business plan, the only additionally device required for the success of our plan is the magnetic nail remover that is located above the conveyor belt. The purpose of this magnetic plate is to separate the nail shards from the wood chippings that are produced by the tub grinder. Once the underside face of this magnetic plate is fully occupied by nail fragments, it must be manually displaced over the bucket placed on the side of the conveyor belt in order to discard of the nails. Once cleared, the plate is relocated over the conveyor belt and is ready for use. Essentially, the process can be simply broken down into 3 different steps:

1. Wooden pallets and rail cars fixed with nails at the joints are piled up.
2. A worker will manually place the wooden pallets and rail cars inside the 100 Tub Grinder. 1000 Tub Grinder shreds the wood and separates the nails using a magnet located above the surface of the conveyor belt (displayed in the solidworks model below). After approximately 5 pallets / railway car supports are processed, someone must manually move the magnet out from over the conveyor belt, resulting in the relocation of the nail shards into a bucket beside.
3. The nails will go to a metal recycler where they will be repurposed and woodchips will be packed up and sold for several different uses.

Figure 3.1 (left) and 3.2 (right) - Demonstrates movement of magnetic plate
Our system can be viewed as a Black Box Model characteristic of its inputs and outputs without even knowing of its internal workings. The input of our system is the wooden pallets attached with nails at their joints which are sent to the wood chipper. The wood along with the nails will be chipped and will fall on the magnetic conveyor belt. Nails being iron will cling to the sides of the conveyor belt where magnets are placed. These nails collect in the sliding box at the end of the conveyor belt as shown in Figures 3.1 and 3.2 on the previous page. The nails will be removed manually from the box and either be discarded or recycled back in the factory. On the other side the wood chips will fall off on the other side of the belt and collect in bags which could be used as mulch for landscaping or to produce energy as a biofuel source.
Cost and feasibility analysis

In order to conduct a complete and legitimate cost analysis, we decided to breakdown the costs into two separate entities: initial input costs and resulting benefits. As interpreted by our team, the initial input costs accounted for any required material or service that was required before any profit was gained. Likewise, the resulting benefits quantified the resultant product and measured the profit projected by our analysis. The breakdown of costs, along with justification of purpose, is described in further detail below.

### Breakdown of Costs

<table>
<thead>
<tr>
<th>Necessary Inputs {Initial Costs}</th>
<th>Cost / Profit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Pallets &amp; Railcar Supports</td>
<td>free (already have)</td>
</tr>
<tr>
<td>2. Morbark 1000 Tub Grinder</td>
<td>$50,000-150,000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Resultant Outputs {Final Profits}</th>
<th>Cost / Profit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Approx. 1,200 bags of mulch</td>
<td></td>
</tr>
<tr>
<td>- 6’ x 8’ x 20’ standard industrial rolling dumpster = 960 ft³</td>
<td></td>
</tr>
<tr>
<td>- 960 / 2 (to account for unoccupied dumpster space) = 480 ft³</td>
<td></td>
</tr>
<tr>
<td>- 480 (volume of wood) / 0.4 (ft³ per bag of mulch) = 1,200 bags</td>
<td></td>
</tr>
<tr>
<td>2. @ $2.50 per bag</td>
<td></td>
</tr>
<tr>
<td>- Retailers (i.e. Home Depot, etc) sell for $5-6 per bag of mulch</td>
<td></td>
</tr>
<tr>
<td>- Assumed Retailers sell for over double purchasing price</td>
<td></td>
</tr>
<tr>
<td>3. Net profit of $36,000 per year</td>
<td></td>
</tr>
<tr>
<td>- $2.50 x 1,200 bags of mulch = $3,000 per month</td>
<td></td>
</tr>
<tr>
<td>- $3,000 per month x 12 months per year =</td>
<td>$36,000 per year</td>
</tr>
</tbody>
</table>
Life cycle analysis

Our system follows a ‘cradle to grave’ as well as ‘cradle to cradle’ cycle. Wooden pallets along with iron nails were difficult to reuse and recycle. And thus we thought of chipping the wooden pallets and then separating the wood chips from the nails. This way, both the outputs i.e the wood chips and the iron nails could be reused separately. The wood chips will be packed in bags and sold as mulch. This mulch can be evenly spread in gardens and children parks for better enhancement of the greenery. The wood chips can also be burnt to produce energy perhaps as a biofuel source. The iron nails can be either sold off as scrap or even be melted and put back to use in the factory for the production of steel making it a cyclical cycle instead of a linear one. This way our system follows a ‘cradle to grave’ cycle in case of the wood chips and ‘cradle to cradle’ cycle in case of the nails.

Therefore, taking Life Cycle Analysis into consideration, we took steps which would help either reuse or recycle the scrap materials or bring profits to the company by selling the waste. We assessed the environmental impacts at each step of our process making sure that no harm is done to the ecosystem and yet everyone is benefitted be it ArcelorMittal or their customers.
Conclusion

Our final design was the 1000 Tub Grinder which has many options that can be included in the machine. Some of the features we chose were the electric model, which would save money and emissions compared to if it ran off gasoline, and the magnetized conveyor belt which would easily separate the metal from the wood. This design would help make ArcelorMittal $36,000 dollars every year after paying off the initial payment. Although in the long run design would make a decent extra sum of money the initial cost of the machine can be quite costly.

With this design in place ArcelorMittal can decide what means they would want to sell the wood chips and what price they will get the machine at. This machine will last for a long time and ArcelorMittal would only have to buy one to see profit. This machine will help the company transition into a more ecologically sustainable company.

Throughout this project our group learned several things. We learned how to do constructive research into a company to help understand their needs and create a design that suits their company. We also learned to do research into solutions that have already been tried as well as options that we could work off of rather than having to create something completely new from scratch. This project helped introduce us into the projects that we could be dealing with when we get out into the field of our respective engineering fields.
References


Acknowledgements

The WoodChippers would like to thank Professor Ritter for her guidance throughout the duration of the project. In addition, we would like to thank ArcelorMittal for providing us with a legitimate real-world problem, allowing us to develop and showcase our design skills.

Penn State University
Professor Ritter
The Entire EDesign100 Team