Transportation in a Breeze

General Electric

EDSGN 100
Section 25
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Executive Summary or Abstract

The residents of Pittsadelphia, Texas have expressed a great deal of concern about the smog emissions from General Electric’s Tier II locomotives that are currently used to transport coal and freight in and out of the city. The smog is generated by the emission of NO\textsubscript{x} by the trains engine. To solve this problem we developed an electric system powered by both solar panels and wind turbines. This would ideally reduce emissions by 100% as well as costs over a two year span by about 70%. Thus this system will satisfy the residents of Pittsadelphia.

Introduction and Problem Statement

The current Tier II locomotives that G.E. still have employed for shipping do not meet the current EPA standards. The residents of the city Pittsadelphia have requested changes to be made as a means of reducing the smog in the city that results from the emissions from the locomotives. The people claim that the smog is reducing their quality of life by causing multiple health problems as well as environmental problems. The high levels of smog emission is a huge issue and on the current path shows no signs of stopping without our interference. We need to reduce smog emissions as much as possible. Ideally we would like to reduce the smog emission to meet the Tier IV standard of a 76% reduction of smog; it would be acceptable to reduce it by 26% to meet the Tier III standards at the very least. To solve this problem we are looking at alternate sources of power. We would like to reduce the use of diesel and replace it with a more renewable source. We are exploring different options such as biodiesel, natural gas or potentially solar or wind power (provided that these prove to be efficient options). If these do not prove to have a sufficient impact, we will look into upgrading to Tier III or Tier IV locomotives.
Background

It has been discovered that smog may lead to various health issues and an overall decrease in the quality of life. Research regarding the costs, capacity and emissions surrounding the current models of GE locomotives was conducted. As of now, approximately 165,000-tons of freight are being transported into or out of the city each day. These trains are currently fit to Tier II specs but are quickly approaching the time for a necessary upgrade to meet Tier III standards as emission regulations grow stricter. Tier II standards have limited the emissions of locomotives to 5.5 g/hp-hr of NO\textsubscript{x} and 0.2 g/hp-hr of particulate matter (PM). The Tier III standards would require that the emission of particulate matter be reduced by 50 percent [3]. The current model, generating power through combustion engines running off of diesel fuel, costs about $347 million in diesel over a two year span.

Customer Needs

Our criteria were generated with the best interest of all of our stakeholders in mind. The first of these needs is smog reduction. As EPA requirements become more and more stringent, it is important for locomotive manufacturers to keep up and continue to improve systems to produce less of emissions. The citizens of Pittsadelphia as well are largely in need of these smog reductions in order to improve their quality of life and prevent rampant pollution in their communities. It was decided that reducing emissions to Tier III standards would be acceptable, while reducing emissions to the Tier IV standards would be ideal. We also decided our solution needed to be extremely durable, as constant repairs and replacement of parts could pose issues with costs and efficiency. It would be acceptable for the system to last for two years of use, but ideal for it to last up to five years without replacement. This brought us to our next need of cost efficiency as we are working under the requirement that GE must receive a two-year return on investment. A two year return would be acceptable,
while a one year return would be ideal. The loudness of our solution was taken into concern as well as we intend to disturb the citizens of Pittsadelphia as little as possible to avoid the interference with their daily lives. We decided that it would be acceptable for the solution to produce less than 70 decibels, while it would be ideal for it to produce less than 60 decibels.

We chose these decibel levels because if something is over 70 decibels it can cause permanent damage to the inner ear and 60 decibels is the noise level of some slightly intrusive noises. Along these same lines we intended to keep the comfort of Pittsadelphia citizens in mind. As developments are continuously made in energy production, we are aware that various source, such as nuclear energy for example, may cause a sense of uneasiness throughout the city. We decided that a 70% approval rating from a survey of the public in regards to comfort would be acceptable, while 100% would be ideal. Power output was one of our main priorities as our solution needed to perform at the same level of output as current systems in order to be successfully integrated into use. A generation of about 2000 horsepower would be acceptable, while 2700 horsepower would be ideal. The type of fuel was a need taken into consideration as it needs to be sufficient in output and cost efficiency. We decided that the current cost and output of diesel fuel ($360 million over the two year span) would be acceptable, while cutting that cost in half would be ideal. Finally we decided that our solution needed to be aesthetically pleasing to the public in the interest of keeping community disturbance to a minimum. We decided that a 50% aesthetics approval rating from the public would be acceptable, while 75% approval would be ideal.
Table 1. The table shown above displays the AHP Matrix that was utilized to create the relative weights that were placed on our customer needs, thus aiding in the process of deciding which idea to proceed with.

<table>
<thead>
<tr>
<th>Concept</th>
<th>Smog Emissions</th>
<th>Durability</th>
<th>Cost</th>
<th>Loudness</th>
<th>Comfort</th>
<th>Power Output</th>
<th>Flavor</th>
<th>Pretty</th>
<th>Total</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smog Emissions</td>
<td>1</td>
<td>0.5</td>
<td>4</td>
<td>3</td>
<td>6</td>
<td>1</td>
<td>6</td>
<td>10</td>
<td>31.50</td>
<td>0.20</td>
</tr>
<tr>
<td>Durability</td>
<td>2</td>
<td>1</td>
<td>8</td>
<td>6</td>
<td>12</td>
<td>2</td>
<td>12</td>
<td>20</td>
<td>63.00</td>
<td>0.40</td>
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<tr>
<td>Cost</td>
<td>0.25</td>
<td>0.125</td>
<td>1</td>
<td>1.33</td>
<td>1.50</td>
<td>2</td>
<td>1.50</td>
<td>2.50</td>
<td>10.21</td>
<td>0.07</td>
</tr>
<tr>
<td>Loudness</td>
<td>0.333333</td>
<td>0.166666</td>
<td>0.751879</td>
<td>1</td>
<td>2.00</td>
<td>0.33</td>
<td>2.00</td>
<td>3.33</td>
<td>9.91</td>
<td>0.06</td>
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<td>Comfort</td>
<td>0.166666</td>
<td>0.083333</td>
<td>0.666666</td>
<td>0.5</td>
<td>1</td>
<td>0.17</td>
<td>1.00</td>
<td>0.60</td>
<td>4.19</td>
<td>0.03</td>
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<tr>
<td>Power Output</td>
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<td>0.5</td>
<td>0.5</td>
<td>3.030303</td>
<td>5.882352</td>
<td>1</td>
<td>6.00</td>
<td>10.00</td>
<td>27.91</td>
<td>0.18</td>
</tr>
<tr>
<td>Type of Fuel</td>
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<td>0.083333</td>
<td>0.666666</td>
<td>0.5</td>
<td>1</td>
<td>0.166666</td>
<td>1.67</td>
<td>5.25</td>
<td>0.03</td>
<td></td>
</tr>
<tr>
<td>Aesthetically Pleasing</td>
<td>0.1</td>
<td>0.05</td>
<td>0.4</td>
<td>0.300300</td>
<td>1.666666</td>
<td>0.1</td>
<td>0.600024</td>
<td>1</td>
<td>4.22</td>
<td>0.03</td>
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</tbody>
</table>

Grand Total: 156.18 1.00

Concept Generation

In the beginning of the project, we conducted further research about the current systems of locomotives used to transport goods. Research about GE innovations, as well as many other methods of transportation and power generation provided us with a sufficient basis to begin generating potential paths to take moving forward. In class, each group member began generating as many ideas as possible in order to provide us with a variety of options to consider. Individual concept generation is beneficial as it eliminates groupthink, and also prevents ideas from being lost in the shuffle as a group can often result in too much information to process. After each member had completed their list of possible solutions, we came together to share our own individual ideas. We discussed the feasibility of the suggestions set forth. We then compiled a list of realistic ideas that were worth real consideration moving forward, those that we deemed were worth including in the concept selection process of the design loop. We decided to proceed with the possibilities of upgrading trains to a higher tier, using alternative fuels such as natural gas or biodiesel, using
an alternative power source, using road vehicles, transporting goods by boat and utilizing air travel.

**Concept Development, Cost-Benefit Analysis and Selection**

The TASC method was utilized as a means of measuring group opinions on each if the concepts as well as testing for the creativity of each idea [7]. After we all completed the program, TASC ranked all of our ideas according to the responses we gave. The top three are displayed below in the order of their ranking.

<table>
<thead>
<tr>
<th>Upgrade Concept</th>
<th>Alternative Fuel Concept</th>
<th>Alternative Power Source</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Figure 1.</strong> The figure above depicts our top idea according to the TASC selection method, which was to upgrade all locomotives to Tier III and Tier IV.</td>
<td><strong>Figure 2.</strong> The figure above depicts our second best idea according to the TASC selection method, which was to convert trains to run on alternative fuels to diesel such as Biodiesel or natural gas.</td>
<td><strong>Figure 3.</strong> The figure above depicts our third best idea according to the TASC selection method, which was to convert trains to run on alternative method of power that utilize renewable resources rather than fossil fuels.</td>
</tr>
</tbody>
</table>

After using the TASC program, we constructed a powerpoint with each of our ideas in which we went into more depth with our research of each concept. We discussed what means would need to be used in order to actually integrate these concepts into use by General Electric. We then compared each concept on the basis of how well they met our defined customer needs. Finally, we figured out how much each concept would cost over a two year span and then compared them to how much it would cost to run the locomotives the way they are for two years (cost analysis of final concept is show below). Although each of the final ideas would be extremely effective in accomplishing our customer needs, we decided to proceed with the system utilizing renewable energy. This was ranked third according to the
TASC selection system, but we were compelled to continue with it as costs would be easily covered in short time, output would be unaffected and emissions would be virtually eliminated. We also felt that this was our most creative idea, and therefore was worth pursuing from many different angles. The charts shown below demonstrate the costs and benefits that the switch would result in. It would cost approximately $65,000,000 for the fifty wind turbines [1], while the solar panels would cost roughly $167,000 [5]. Power lines to carry the generated energy down the track to the locomotives would cost approximately $3,000,000 [6] and installation and maintenance costs for the system would be around $35,000,000. A GE spends approximately $350,000,000 in a two year span on diesel fuel for locomotives, our costs would be easily covered in this time, actually saving the $245,533,000. Our return on investment would easily meet GE’s goal of two years.

![Cost over 2 years](image)

**Figure 4.** The figures shown above demonstrate the costs of current systems over a two year period as compared to our model of transportation. The green section represents current operating cost, while the red section represents costs that we are proposing and blue represents the potential money that could be saved over the two year period.
Design Review

The design review brought to light a few different issues with our system. There are some safety aspects of our concept such as the possibility of someone being unintentionally electrified by our tracks. This matter was taken into great consideration as safety must be held to the utmost importance. Our classmates also suggested that we look into tax breaks from EPA funding to reduce costs. Additionally, they mentioned that our systems diagram was a tad unclear. Because of this, we reconstructed our systems diagram, which produced a better image of the system of our product as well as displaying its inputs and outputs. After that, we also produced a CONOPS so that we could better explain the step by step procedure of our concept. We redesigned the rails to make it so there is a much smaller chance of being electrocuted by making the rails split with the wire in the middle to reduce the possibility of accidentally touching the electrified areas. They also showed concern with the reliability of solar and wind energy. In response to this, we will create a system where any excess energy we create we will sell to the city which could also afford us the opportunity to buy it from the city in the event that the system needs energy. Ideally these costs would equal themselves out.

Description of Final Design

Our final design incorporates auxiliary wind powered energy with assisted solar power to replace the existing diesel powered generators. Wind turbines will be located near the track and power will be transported to the train through the use of power lines, as well as an electrification of the rails. The solar panels will be mounted on the locomotive and provide additional power during the day in time of intense sunlight. The wind turbines that we selected to base our calculations off of are 1.5 Mw turbines that are made by GE and produce, on average over a year, just over the approximate amount of energy that the current diesel
generators provide the train with [1]. We will integrate these generators into the local city power system so that at times when our power production methods are not able to keep up with our power needs, it can draw from the city power grid. Conversely, when more power than necessary to run the locomotives is produced, power will be fed back into the city. We have chosen to use 50 turbines so we will be producing greater than the approximate average output of the diesel motors [2]. To counter the hazard of electric shock, we will be incorporating an adapted version of an already existing “third rail system” in which the power is fed through a separate rail that the train uses to draw power from. This design is currently used in subway systems as it is safer for anyone passing the rails. Our adaptation will have the wire buried beneath one of the rails and then fed up inside it. The rail is specially designed to have a channel on the inside that protects contact points that touch the wheels of a passing train which conducts its power to the motor, similar to how some model trains work beneath a Christmas tree. The locomotive would travel on the route shown on the map below in order to deliver the freight and coal to Pittsadelphia.

Figure 5. The figure above depicts a map of Texas with the route that these trains would take to Pittsadelphia from the starting point of the freight and coal labelled in red [4].
Figure 6. The figure above displays the systems diagram for the process, creating a visualization of the inputs and outputs of the various subprocesses for our model.

Figure 7. The figure above displays the concept of operations for our model, also known as a CONOPS, which shows a more detailed description of how the process of transportation will occur, complete with numbers describing the amounts of energy and freight involved in each step.

Conclusions

Our design replaces the existing diesel generators with onboard solar power and nearby wind power. Some positives about implementing the new system would be that these locomotives would reach as close to zero emissions as possible under the given parameters. Also, the elimination of the use, and therefore the cost of fuel brought the price of the project easily
inside our budget. One potential con of incorporating this new design is that the trains of this design would not be able to run on ordinary tracks that are not supported by this system. Additionally, it may take some time for the system to be installed and implemented due to the infrastructure changes that would need to occur. Moving forward, as wind turbine technology advances we would hope to implement this system on a larger scale, in order to reduce locomotive emissions across the country. During this project we have learned about how much green energy production has progressed over the years due to the technological advancements in recent history. We also gained a great deal of insight into how and why the locomotive industry is advancing as a result of government regulations and advancements in energy.
References


