Transportation Solution for General Electric

EDSGN 100
Section 22
Dr. Ritter
14 November 2015

Industrial Team
Emily Nix (ecn5049@psu.edu)
Amanda Welsh (acwelch0321@gmail.com)
Tomas Alonso (tomasav96@gmail.com)
Anuj Kurade (kurade.anuj@gmail.com)

Figure 1. Seen above is the prototype for our solution to GE’s transportation issue.
Abstract:

One of the main concerns of residents in the city of Pittsadelphia is smog emission. We are aiming to design a more sustainable, eco-friendly freight transportation system. To do so we will take into consideration customer needs, and use design processes like an AHP matrix, a concept selection matrix, and a cost-analysis chart to come to final design. Our final design will be upgrading all trains to Tier III and switching the fuel to B20 Biodiesel.

Introduction and Problem Statement:

The main problem we are dealing with is reducing smog emissions. Today, global warming is a huge issue. Based off of GE’s presentation, their new Tier 4 model is the cleanest, smartest, most fuel-efficient diesel-electric locomotive for heavy-haul freight. This model will meet EPA tier 4 requirements and reduce NOx and PM emissions by more than 70%. Purchasing the new Tier 4 engine technology requires no after treatment, which saves more than $1.5 billion in infrastructure and operating costs. From the facts, the newest tier 4 upgrade is highly beneficial to the environment, meets the issue of reducing smog, while simultaneously saving money.

Pittsadelphia would like to create a more sustainable, eco-friendly freight transportation system. We aim to reduce smog emissions and have a cost effective solution, while maintaining or increasing the freight capacity. Approximately 165,000-tons of freight or minerals per day travel in or out of the port city of Pittsadelphia via rail. Due to this, smog from locomotive emissions is currently a main concern. The reduction of smog is crucial because of the harmful NOx emissions, which affect the population and the environment. We plan to achieve our goal by analyzing different types of fuel and cost-effective methods of freight transportation, while keeping in mind EPA requirements, public opinion, safety, and capacity of the locomotives.

Background:

Smog emissions are a main concern of GE. Smog pollution intensifies pollen allergies and asthma. Other side effects of smog pollution increasing are irritated eyes, noses, and lungs from bad air days. Based on the information given in the GE presentation, NOx, PM (Particulate Matter), and CO₂ are what emissions consists of. NOx is formed when Oxygen and Nitrogen are heated. The higher the temperature the more NOx emitted. PM is not one substance, but anything collected on a test filter. CO₂ is formed directly proportional to fuel consumed. The less fuel consumed, the less CO₂ emitted. Biodiesel (B20) is cheaper than regular diesel fuel by 14 cents. B20 biodiesel gas also has 109% of energy of one gallon of gas, or 99% of energy of one gallon of diesel. Rail shipping holds the largest capacity in comparison to sea, truck, and plane transportation. However, rail is not as environmentally friendly as sea transportation. In research found in the GE project we found that B20 Biodiesel fuel has 99% of the energy of diesel fuel. We also know that diesel fuel costs $3.06/ gallon and biodiesel fuel costs $2.92/
gallon. Because GE already has the trains that need adjustments and is a large corporation, our solution seems to be feasible. Due to all the information provided by GE, and researched data on smog emissions and the affect it has on everyday lives, it is necessary to make a more environmentally friendly train for GE to use for their transportation.

**Customer Needs:**

To evaluate the designs, we chose to analyze the categories of time efficiency, reduction of smog, capacity, cost effectiveness, public needs, safety, and size. We chose these different criteria because we felt like if these problems were kept in mind, we would be able to accurately solve the problem Pittsadelphia is having. When we calculated the weights of our criteria, we were not surprised that the environmental benefits were the most important category. Because the citizens and every stakeholder were concerned about the emissions, we aimed to focus our energy on that specific issue, while also keeping in mind the other factors. Our next two highest factors were capacity and time, and this is because we wanted to make sure the system was highly efficient and could transport the same amount, if not more, freight and minerals than the previous system.
Concept Generation and Development:

On day one of concept generation, we all had a variety of ideas. Many of them consisted of using alternative methods of transportation for part of the system, then switching methods into the city. We also came up with a lot of ideas that involved altering the trains. From there, we analyzed and combined our ideas to form ones that would be considered further. Our ideas consisted of using trucks from a common port into the city, using ships into the city, changing the fuel of the trains to biodiesel, upgrading the trains to tier III, and flying planes into the city and using trucks and trains out of the city. After using the concept selection matrix, we found that our two most favorable solutions were tier III trains and biodiesel fuel. Although trucks and planes can be fast, we were glad to eliminate the use of them because of their limited capacity.
It was also a good idea to eliminate ships because of their lack of time efficiency, even though they can be environmentally friendly. Overall, utilizing trains, but altering them in some way was the way to go. We could take the aspects of trains that were already efficient, such as capacity and time efficiency, and make it so that they were also extremely cost effective and environmentally friendly. From there we thought that it might be a good idea to combine our two ideas that were left, for ultimate efficiency and smog reduction. Moving forward, because we were unsure if combining would be the best option, we decided to consider biodiesel fuel, tier III trains, and the combination of the two ideas.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Trucks from common port to city</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>2.09</td>
<td>6</td>
</tr>
<tr>
<td>2. Ships from different ports to city</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>3.11</td>
<td>4</td>
</tr>
<tr>
<td>3. Change fuel to biodiesel</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>1</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td>4</td>
<td>3.45</td>
<td>2</td>
</tr>
<tr>
<td>4. Tier 3 trains from common station to city</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>3.32</td>
<td>3</td>
</tr>
<tr>
<td>5. Planes into city, trucks and trains out</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>2.71</td>
<td>5</td>
</tr>
<tr>
<td>6. Half to tier 3, change all fuel to biodiesel</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>1</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>3.62</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 2. The above table shows how we ranked our ideas, based upon the weighted criteria.

Design Review:
We went into the design review with a design that allowed for only half the trains to be upgraded to Tier 3, while switching all of the trains’ fuel to biodiesel. However, after consulting with various groups, we found that upgrading only half our trains wouldn't have the desired results in smog reduction. We found from this that is was necessary to upgrade all our trains to Tier 3, while maintaining the idea of switching the fuel to biodiesel.

Cost-Benefit Analysis and Concept Selection:
For our Cost-Benefit Analysis, we started by making some assumptions. We assumed it would be a 500 mile trip into the city for freight and coal trains at an average of 50 miles per hour. We then assumed coal and freight trains would leave the city empty, but still weigh 1000 tons per coal train and 500 tons per freight train. Also, the locomotives would have a horsepower of 4500hp and an operational time of 20 hours. We also assumed that for B20 biodiesel, we would have to upgrade the engines.

For the first portion of our Cost-Benefit Analysis, we analyzed the option of switching the fuel to biodiesel. We started by finding the overall cost, which is $55 million, consisting of a
$50 million ($1 million per locomotive) upgrade and $5 million ($100,000 per locomotive) after treatment cost. Another cost of biodiesel would be that it is a little less efficient than diesel and it produces more NOx, but we assume that cheaper cost and the after treatment makes up for that. We then found the benefits of biodiesel fuel. We did that by calculating the cost of fuel for biodiesel coal and freight trains per day and subtracting that total from the total cost of fuel for diesel coal and freight trains per day. We then multiplied that by 365 to find how much cheaper biodiesel fuel is per year. Biodiesel fuel is $9.6 million cheaper per year and should pay off in less than six years. Because of one gallon of biodiesel fuel having 99% of the energy that one gallon of diesel fuel has, it will most likely pay off in around six years. Another benefit from biodiesel fuel is the reduction in particulate matter. It will decrease by about 97 kg (started with 807kg), or 12% (1). We found this percentage on a biodiesel emissions calculator.

We then moved onto our next Cost-Benefit Analysis, upgrading the trains to tier III. We found that the total cost of upgrading would be $42.5 million, consisting of a $37.5 million ($750,000 per locomotive) upgrade and a $5 million ($100,000 per locomotive) after treatment. Then, we moved on to the benefits. We found that tier III is 11% more efficient than tier II so we multiplied the cost of tier II trains by .89 to find the cost of fuel per day of tier III trains. We then subtracted that number from the cost of fuel per day of tier II trains. After multiplying that number by 365, we found that tier III trains are $23.2 million cheaper per year. This means that this solution will pay off in two years. Because of the after treatment, we assume that NOx will be reduced. Upgrading to tier III means a 50% reduction in particulate matter, meaning that it will be reduced by 405 kg per day.

Our final Cost-Benefit Analysis consisted of our combination of ideas. We found that the total cost was $92.5 million, consisting of a $50 million ($1 million per locomotive) upgrade to biodiesel, a $37.5 million ($750,000 per locomotive) upgrade to tier III, and a $5 million ($100,000 per locomotive) after treatment. To find the benefit of this, I took the cost of fuel for tier II biodiesel trains per day that I had calculated earlier and multiplied it by .89 (due to an 11% increase in efficiency). I then took this number and subtracted it from the cost of fuel for diesel tier II trains per day to find how much cheaper this solution would be per day. When I multiplied that by 365, I found that this solution would by $31.8 million cheaper per year. This means that our solution would pay off in less than three years. Because of one gallon of biodiesel fuel having 99% of the energy that one gallon of diesel fuel has, it will most likely pay off in around three years. Also, the NOx emissions will be reduced due to the after treatment. Because we combined solutions, there will be a 62% reduction in particulate matter, 50% from upgrading tier III and 12% from changing biodiesel fuel. This means that the trains will emit 502 kg less PM per day. Clearly this solution was the way to go. Not only were we reducing the PM emissions by the highest percent, but also it was also only taking three years to pay off. Based on this reduction of smog and low cost, our combination of both biodiesel fuel and tier III trains was our best option. This solution met our cost and environmental requirements, but also
satisfied customer needs because of the smog reduction, maintains capacity and time efficiency due to the same number of trains, and meets size requirements because they are still GE trains. The only factor that this solution does not exceed is fuel efficiency. Biodiesel fuel is less efficient than diesel fuel, but not by very much, so it does not have a very large impact on our cost or environmental results. In conclusion, upgrading to tier III trains and switching to biodiesel fuel was our best solution. Not only were we reducing the PM emissions by the highest percent, but also it was also only taking three years to pay off.

**Description of Final Design:**
Our final design is the culmination of two of our best ideas. We have upgraded all our trains to Tier 3 and also changed the fuel to a B20 biodiesel fuel technology. Our design impacts various customer needs such as Our updated train solution reduces PM emissions by 62%. NOx will be reduced because of the after treatment. Our design saves $31.8 million every year. This allows our customer to regain the initial investment of $92.5 million in a span of 3 years, after which, profits can be made. Our design uses trains over any other method as they have a very large freight capacity, while still meeting EPA requirements. Because we are using the same trains, capacity will be maintained, as well as on-time delivery. Therefore, society as a whole sees the benefit with lesser smog and efficient delivery. Overall, this is an economically viable solution because it will pay off in three years, while reducing the major concern of smog.

**Systems Diagram:**

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

**Figure 2.** This figure shows how we systematically represented our design.
Concept of Operations:

Figure 3. This shows how we visually came up with our design.

Conclusion:

After all, it is impossible to make something perfect, but in this project we tried to come with a solution where the loss in something was a gain in something more important. As stated before, the main problem we were dealing with was reducing smog emissions. Today, global warming is a huge issue, and reducing smog by a great percentage would be a great help for the global warming. To come up with a solution, we had to analyze all of the ideas explained previously. Many of them consisted of using alternative methods of transportation for part of the system, then switching methods into the city. Also some that involved altering the trains.

One of the most important things that we had to take into account when choosing the best solution was the customer needs, such as time efficiency, reduction of smog, capacity, cost effectiveness, public needs, safety, and size. It was hard to come with the correct solution, since every of the ideas had pros and cons. At the end, the cons of our decision were that biodiesel fuel is less efficient than diesel fuel, but just for a small percentage so it was not such a con. The other con was that changing the locomotives to Tier 3 did not give us the reduction in smog that Tier 4 would have give us. But on the other hand, changing to Tier 4 would have cost a lot of money so it is a pro and also a con. The most important pro that we were able to achieve was the smog reduction and the change to biodiesel. After all, the investment in these changes would pay off in less than three years. Knowing where the design would go from here is hard to know. We would say that the first step is to try the solution with only a small part of the trains, and see the results. If the result in those trains is positive then the company could apply the changes to all of the locomotives.

This project gave us a different way of thinking, since there were a lot of ideas of how to achieve the solution and all of the ideas were a good solution for the problem depending of the point of view of the person. We learned how to choose from one decision versus another when
having the same resources and how to apply cost analysis and benefit to the solution. This analysis helped us to see what the specific numbers were and how these numbers would benefit the company.

References: