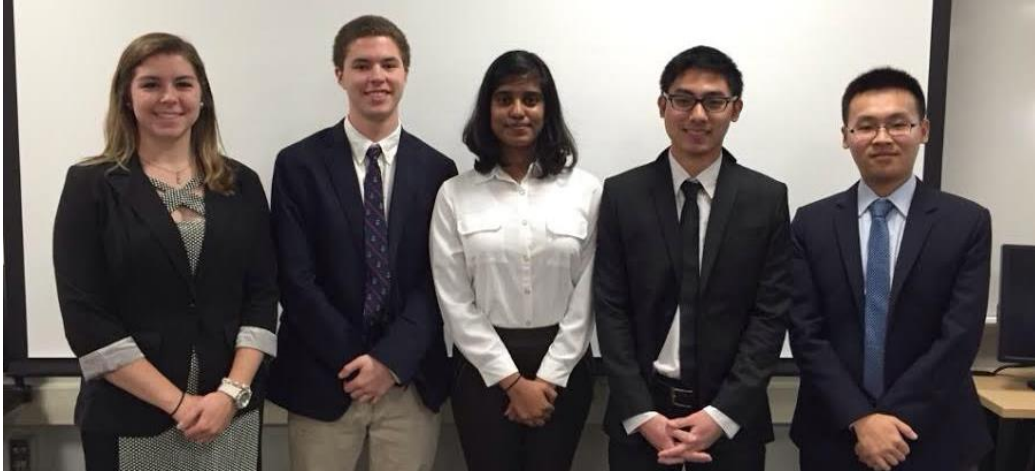


EDSGN 100: Introduction to Engineering Design

Section 09, Team 6

GE Design Project: Freight, Fuels and Emissions



Submitted by:

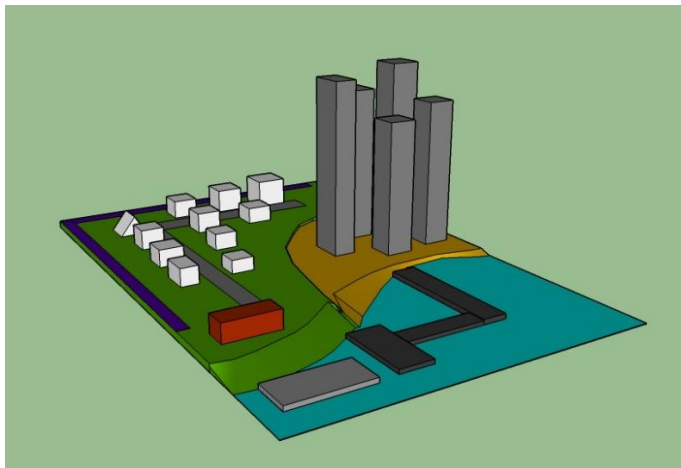
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Submitted to: [Xinli Wu](#)

Date of Submission: December 15, 2015



PennState



http://www.personal.psu.edu/wb15038/Project_II/edsgn100_fall15_section09_team6_dp2.pdf

Abstract

The purpose of this project was to design a cost efficient transportation system that minimizes emissions without reducing freight capacity for the city of Pittsdelphia. The team has chosen to do so by upgrading the tier of locomotives from tier 2 to tier 3 and increasing transportation by sea.

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Final Edit: [Weizhi](#)

I. Introduction

Designing an extensive, involved transportation system is a feat accomplished only by the collaboration of countless individuals, copious amounts of planning, and a solid construction of the project. Though this process may be involved, it is not impossible. Cities all around the world have adapted to the ever-growing needs of humanity by expanding transportation systems and implementing new, innovative ways to improve what has always been the task: going from one point from another. Modes of transportation have included by foot, by buggy, by railroad, by boat, by vehicle and by plane.

With new and innovative technology come problems that have yet to be solved. These problems include technical difficulties, operator inefficiencies, and most importantly, pollution from emissions. In fact, over 50,000 Americans die every year due to health complications caused by air pollution. This is a worldly phenomenon, with heavily-populated countries, such as China and India, having greater mortality rates and worsening health hazards caused by inhaling pollutants in the air.¹ With the human population growing exponentially, transporting people and freight are at an all-time high. Pollutions are increasing, and General Electric is looking for a solution that will bring in the future of freight transportation with reduced emissions.

General Electric proposed a problem for a fictitious city, Pittsdelphia, and asked students to fix the outdated system that causes heavy pollution. The residents of the area complained about the smog surrounding them, as the pollution in the air caused numerous health problems. The project proposed by General Electric sparked the interest of five engineering students, who will subsequently have to combat this problem to being a cleaner future with less emissions for future generations. Together, they brainstormed, developed, and designed a process to combat this worldly problem. These students researched, collaborated and came up with a system that is cost-effective, cleaner, and would be accepted by the public. The students accepted this challenge and worked to design a system that would improve a system that ultimately affects all of humanity.

II. Description of the Design Task

1. Problem Statement

Pittsdelphia is experiencing a situation with excessive amounts of smog. The city has approximately 165,000 tons of freight and minerals traveling in and out per day by rail, and the current tier 2 locomotives are approaching age for overhaul. Changes must be made for this port city to meet EPA requirements.

2. Mission Statement

To design a cost-effective approach to an emission-reducing freight transportation system without decreasing capacity by means of upgrading the tier of locomotives from tier 2 to tier 3 and increasing transportation by sea.

3. Design Specification

The team has strictly followed the specifications and our solutions have the following features:

- The existing locomotive fleet is upgraded from tier 2 to tier 3 by installing renovated hardware to capture NOx before exhausting in order to meet the latest emission guidelines set by the EPA.
- An alternative freight shipping by sea is increased and freight transportation by locomotives is decreased.
- An alternative freight shipping must be environmentally friendly and reduce NOx emission.

III. Design Process/ Approach

1. Project Management-Gantt Chart

The team has spent almost two months from the first day the problem was introduced to its completed prototype and documentation. Over the duration of the project, the team spent specific days on various tasks that helped them develop a final system, as Figure 3.1 displays.

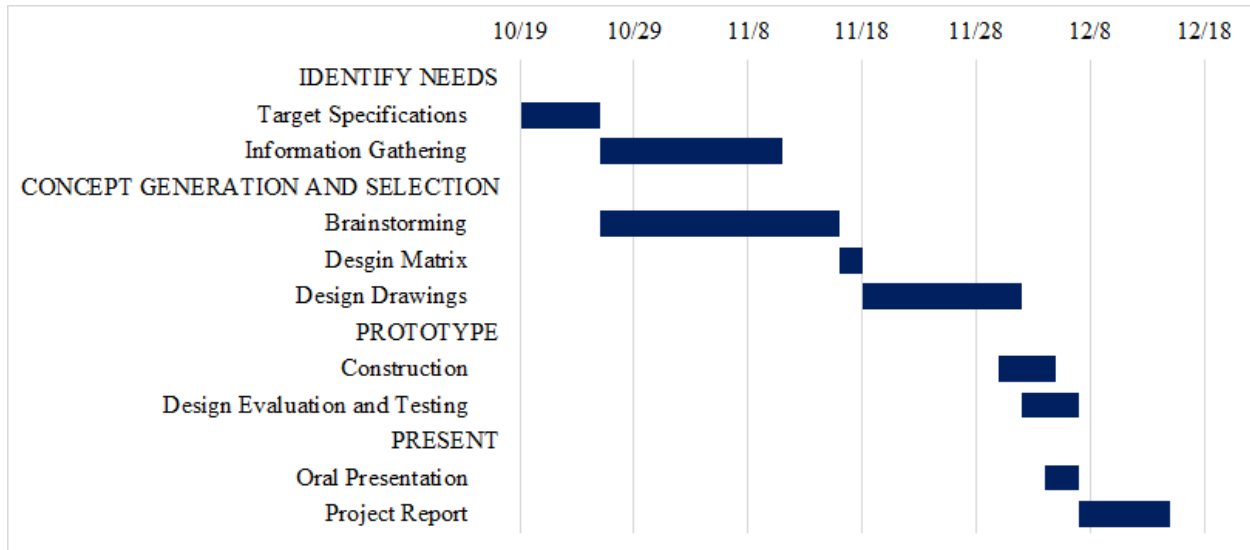


FIG 3.1 Gantt chart

2. Concept Generation

The team has designed five separate solutions to be analyzed before selecting the best design to meet the specifications of General Electric and satisfy the public.

The first design was to increase power by means of using solar energy. While this would be a clean and effective way to produce emissions, the price would be too high. For the amount of electricity that Pittsdelphia, a major port city, would use, the cost would be too high for the purchase, installation, and upkeep of the panels. Sure, there would be a dramatic decrease on carbon emissions, but the costs would be large and the return on investments would take too long. Financially, adding enough solar panels to power a whole city is highly impractical and not cost-effective. Because of the high costs, the public would not respond well to this proposal.

Using alternative fuels was the second design generated by the team. This design would also reduce particulate matter and nitrogen oxide (NOx) emissions. However, the capacity of the transportation system would remain the same. The team believes that there are other solutions available to have reduced emissions and increased capacity of the entire system. With the growing needs of the population, the team feels that the solution must have an increased capacity to be the most effective. Costs are another problem with this proposal. Under the guidelines provided by General Electric, erecting an alternative fuel plant alone would cost one billion dollars. This approach is not cost-effective at all, because the team believes the cost outweighs the benefits in this situation.

The third design was to increase shipping by sea, and to upgrade the tier II locomotives to tier III. By upgrading to tier III rather than tier IV, the locomotives would reach EPA requirements and funds would be saved. The team thought the increased shipping would be the best solution to increase capacity because it is the most environmentally friendly, according to Figure 2, provided by General Electric. By implementing more transportation by sea, the time of transportation is lengthened, but the city benefits from a lower cost, higher capacity, and the lowest impact on the environment.

	Cost	Capacity	Time	Environmental
Truck	+	+	++	
Rail	++	+++	+	++
Sea	+++	++		+++
Air	-		+++	

TABLE 3.2 Comparison of Modes of Transportation

The next idea developed by the team was to sell most of the locomotives for profit and to purchase ships. Since Pittsdelphia is a major port city, the team felt like this could be a feasible approach to the problem. However, upon further discussion, the students decided that the capacity would be severely impacted by the change. Because of this, on time delivery would suffer greatly, resulting in a negative public opinion. Emissions would go down because of the environmentally friendly qualities of the ships and the low number of locomotives, but the negative aspects of this idea are too massive to continue.

The last idea was to increase transportation by trucking and by air. This idea had the lowest freight capacity, since planes and trucks have very little capacity compared to locomotives and ships. Though these methods of transportation are the fastest methods, they are also the most costly and cause the most pollution. Referring back to Figure 2, one can see that the costs are too much and the environmental impact would be overwhelming. The team decided that the short delivery time was a small benefit compared to the astounding negative aspects, which would most likely deter the public opinion from this method.

3. Design Idea/ Concept Selection

Each of the team's systems were tested against the reference design to compare the positive and negative aspects of each idea. The design team then assigned a +, 0, or – to indicate whether the design was better than, similar to, or worse than the reference for that particular feature, respectively. Below, Table 1 provides the criteria that was used to determine the most beneficial system for Pittsdelphia.

Selection Criteria	Concepts				
	A	B	C	D	E
	Increase Solar Power	Alternative Fuel	(Reference) Upgraded Tier Locos and purchase ships	Sell trains, buy ships	Increase trucking/air
Freight throughput/capacity	0	-	0	-	-
Emissions/Regulatory requirements	+	+	0	+	-
Costs	-	-	0	+	-
Public Opinion	-	0	0	-	+
On time delivery	0	0	0	-	+
Sum +'s	1	1	0	3	2
Sum 0's	2	3	5	0	0
Sum -'s	2	1	0	2	3
Net Score	-1	-1	0	-1	-1
Rank	2	2	1	2	2
Continue?	No	No	Yes	No	No

Table 3.3 Concept Screening Matrix

4. Description of the Best Design Selected

Overall, the best design selected was the upgrade of locomotives to tier III and purchase of ships using the difference between the cost of upgrading to tier IV and tier III, which is \$50,000. The entire fleet of locomotives, which is equal to fifty, will be upgraded. Since there will be no change in the number of locomotives that run each day, the freight capacity running into and out of Pittsdelphia will increase because of the added ships. Also, since General Electric defined Pittsdelphia as a “major port city,” little modification and expansion will need to be made to the existing port, which could be a major concern of the public.

Figure 3 displays the benefits of upgrading from tier II to tier III. The particulate matter will be decreased by fifty percent, which will greatly reduce the smog in Pittsdelphia. The public will have decreased health problems because of this drastic change. Also, one of the determining factors of using ships was their low NOx output. For approximately every three and a half pounds per ton mile that a locomotive produces, a locomotive only produces one pound per ton mile.² This is the most environmentally friendly effect, since the public complains about the uncleanliness of the air due to the transportation system.

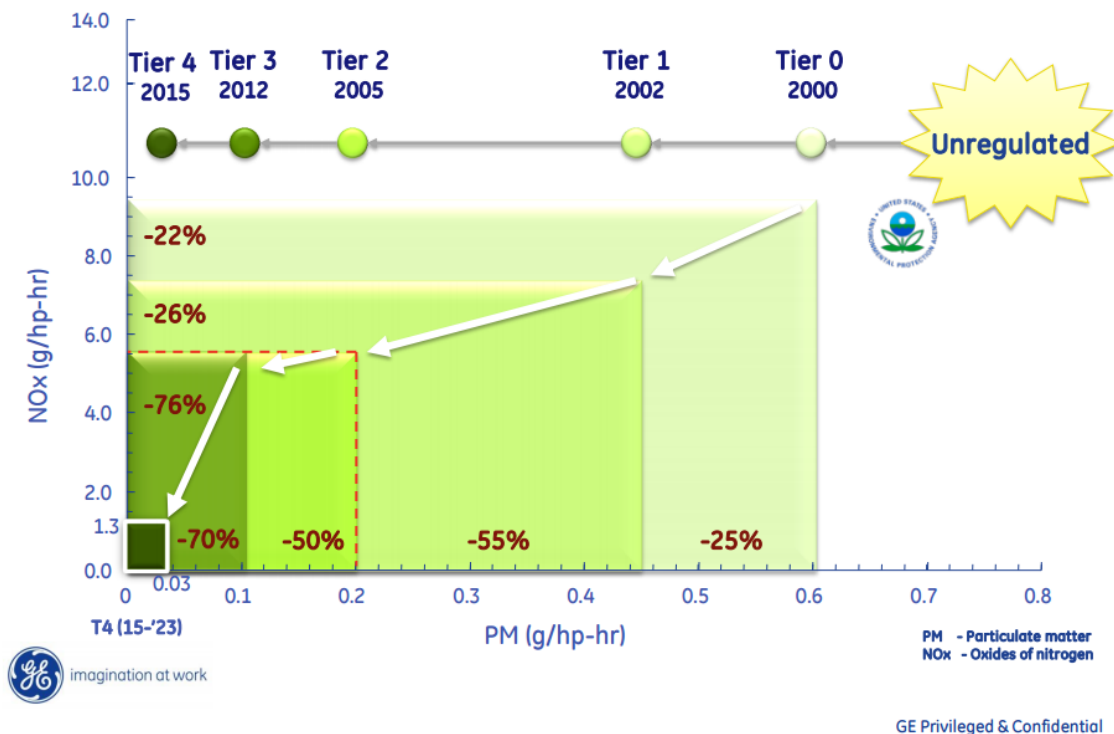


FIG 3.4 Locomotive EPA Emissions

IV. Model and Prototype

1. System Diagram

Legend:

Blue - sea

- Dark grey – port docks
- Light grey – port storage area

Yellow – urban area

- Grey – skyscraper

Green – residential area

- White – resident houses
- Red – port transportation center
- Purple – railroads
- Grey – highways

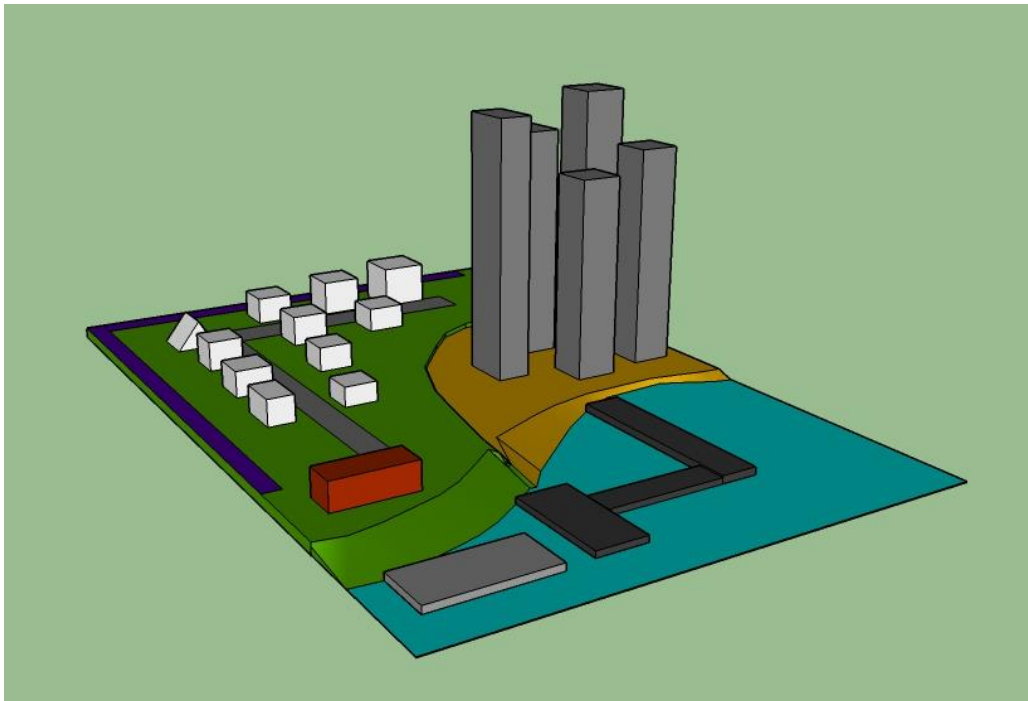


FIG.4.1.1 Design Model (1)

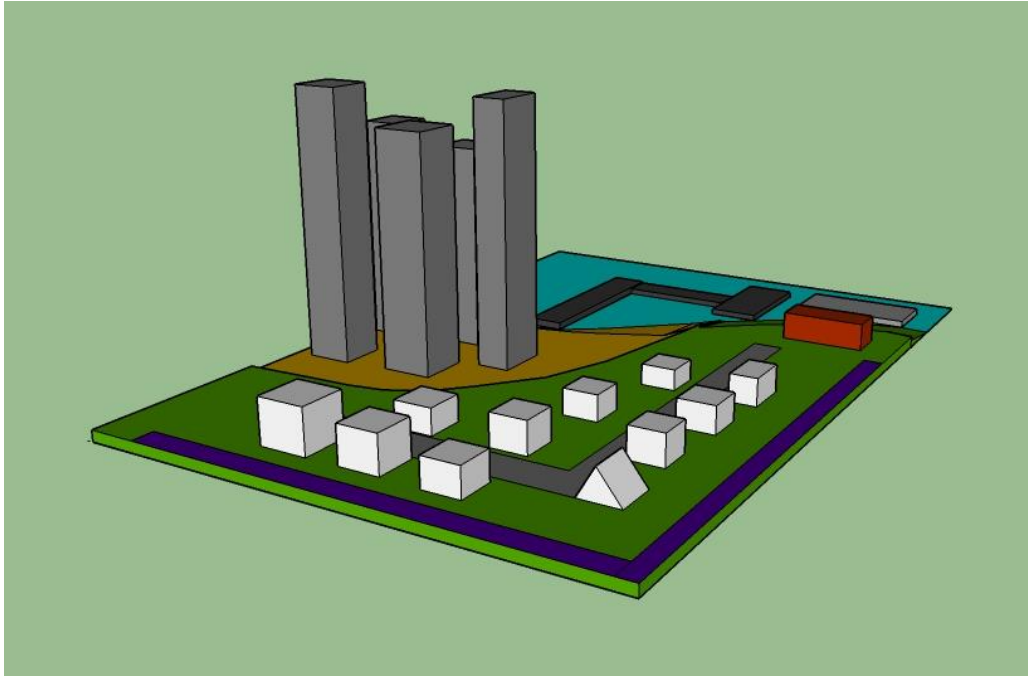


FIG 4.1.2 Design Model (2)

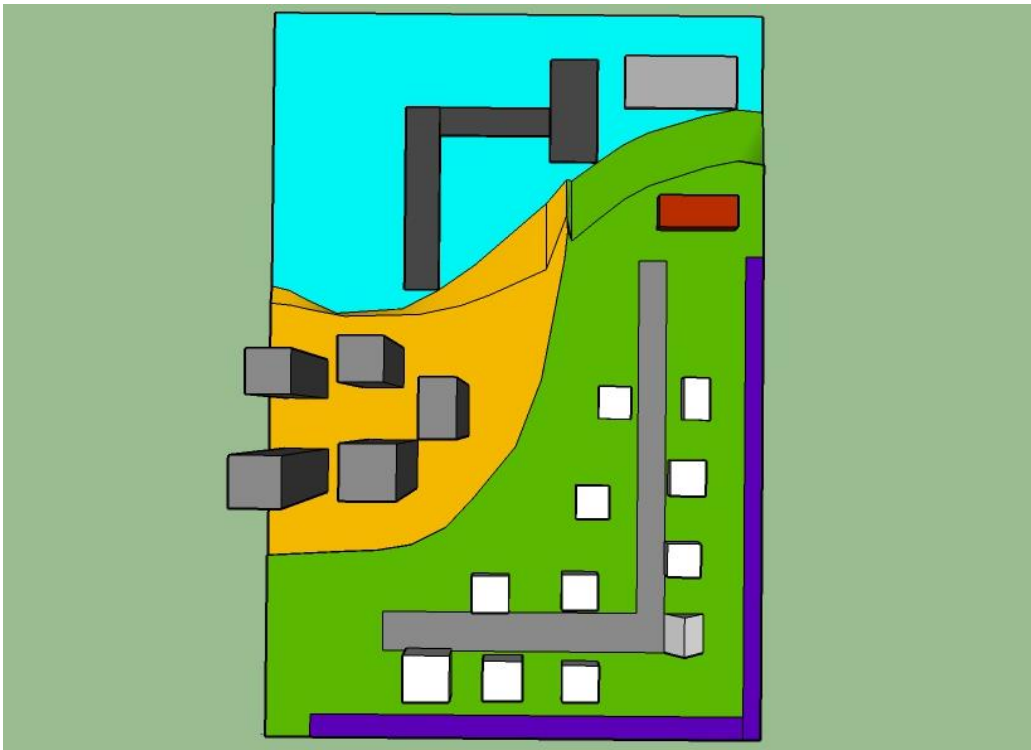


FIG 4.1.3 Design Model (3)

2. Prototype

- a. Prototype scale: 1:1
- b. Actual prototype



FIG 4.2.1 Prototype built (1)



FIG 4.2.2 Prototype built (2)

3. Design Features

This prototype is a very brief city model of Pittsdelphia. Based on the final design, upgrading tier 2 locomotives to tier 3's and increasing the portion of sea transportation are the two main features that this prototype presents. Also, a brief transportation system of the city is built on this prototype.

This prototype is divided up into three parts, sea, urban area and residential area. The sea has the largest portion on this prototype to represent the development of sea transportation. The docks and the storage area are placed. A total of 10 cargos can be seen over the sea. In the design, a larger number of cargo ships should be operating after the purchases of new ships. From the data discussed in previous sections, transportation by ships are the most economic and eco-friendly method of shipping. In this way, emissions will be reduced and we will not reduce capacity either. Railways and highways are built from the port to the city. This fills the gap from the coast to inland, upgraded higher tier locomotives will effectively reduce emissions. Trains and trucks are still unavoidable transportation methods. This is why another feature comes up.

Another feature is the green vegetation. The railroads and highways are designed to be built away from residential area and also surrounded by vegetation. This is intended to reduce the emission to the residential area and therefore reduce residents' complaints.

V. Analysis

The first step taken by the team to arrive at the proposed solution for Pittsdelphia's locomotive emissions problem began with open group discussions about Pittsdelphia's current situation and what can be done to minimize pollution in the area. The group utilized the information provided by General Electric to formulate a design for a new freight shipping system that meets EPA requirements, reduces smog and emissions and maintains freight capacity. To accomplish these design goals the team intends to upgrade tier II locomotives to tier III locomotives as well as a plan to implement more freight shipping by sea. Upgrading locomotives from tier II to tier III reduces particulate matter by 50%. Decreased particulate pollution exposure will make the air safer and cleaner for Pittsdelphia enhancing the health of its citizens and the surrounding environment.

The team considered upgrading to tier IV, but General Electric also made a suggestion to use a different mode of freight shipping which intrigued the group. By not upgrading to tier IV and instead only upgrading to tier III the team would have \$50 million worth of savings which could be used for an alternate freight shipping. The team chose to purchase five new cargo ships for the port city. Compared to the other alternative transportation options like air and trucking, sea proved to be the most logical, economically resourceful substitute. Increasing freight shipping by sea will help reduce emissions of nitrogen oxides, which will again create less pollution in Pittsdelphia's air. Transportation by sea is also safer than locomotive transportation and freight capacity will increase with the addition of more ships. Pittsdelphia is described as already being a port city so only some adjustments would be necessary for the port to accommodate more ships. This could also create jobs for Pittsdelphians which would assist the city's economy. The team did think about using alternative fuel as a possible solution, however the team could not justify spending the one billion dollars that would require since the system is meant to be cost effective.

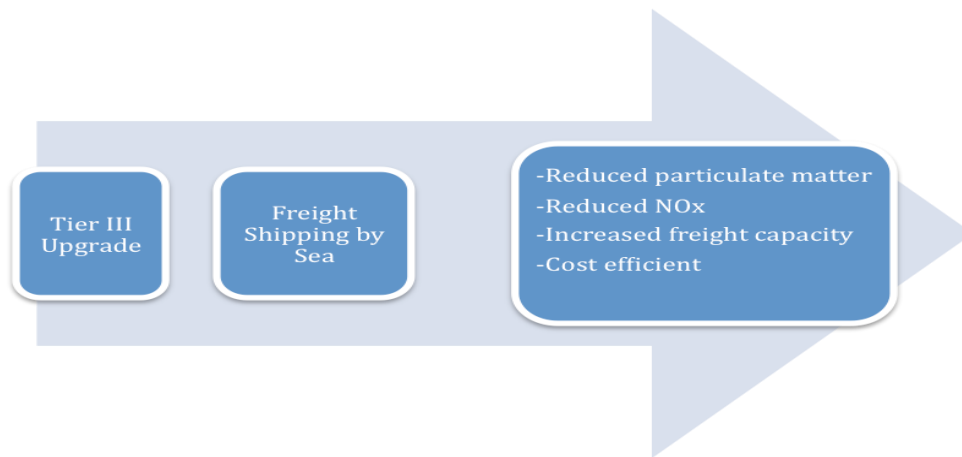


FIG. 5.1 Design Analysis

The mission statement clarified that the new system must be cost effective. The annual fuel cost of the team's system is estimated to be \$383 million. Pittsdelphia's current fuel cost is \$223 million. The team considered this a reasonable increase considering the benefits the system would be providing for the city. With this system in place the city will experience decreased emissions and its citizens will be able to enjoy an improved environment making it a cleaner, healthier place to reside in.

Life cycle analysis:

Input: The main shipbuilding and engine requirements are alloys of aluminium and alloys of titanium. Alloys of aluminium are more corrosion resistant, lightweight and durable making it good for long term use.

Output: Ships have far less emissions than other modes of transportation. Both alloys are recyclable, hence further reducing environmental impact.

Life cycle: The ships are environmentally efficient and sustainable for long term use.

VI. Summary and Conclusions

The team wanted to create an efficient system of transport with minimal emissions. After several brainstorming sessions, design matrices and much research, it was decided that the best way to optimize the capacity and reduce emissions was to increase the number of ships as well as upgrade the tier level from tier II to tier III. The team then designed the prototype, using SolidWorks to design and three-dimensionally print any objects that were not readily available to specifications. The group used collaborative thinking, creativity, and hard work to generate the final product. Each team member contributed by proposing unique ideas that could be incorporated into the design to overcome complications. This was a great learning experience for the entire team and it will greatly benefit to have the knowledge acquired from this project for future engineering endeavors.

VII. Attachment of PowerPoint Slides

GE Design Project: Freight, Fuels, and Emissions

Group 6

Weizhi Liao
Divya Avnoor
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Problem Statement

Pittsdelphia is experiencing a situation with excessive amounts of smog. The city has approximately 165,000 tons of freight and minerals traveling in and out per day by rail, and the current tier 2 locomotives are approaching age for overhaul. Changes must be made for this port city to meet EPA requirements.

Mission Statement

To design a cost-effective approach to an emission-reducing freight transportation system without decreasing capacity by means of upgrading the tier of locomotives and increasing transportation by sea.

Our Solution



The team has decided to upgrade the existing Tier 2 locomotives to Tier 3 locomotives, and to increase shipping by using the price difference between tier 3 and tier 4 to purchase more ships.

Tier 4 upgrade: \$4 million per loco X 50 locos = \$200 million

Tier 3 upgrade: \$3 million per loco X 50 locos = \$150 million

Savings: \$50 million

Assuming \$10M/ship, five cargo ships can be purchased.



Our Solution

	Cost	Capacity	Time	Environmental
Truck	+	+	++	
Rail	++	+++	+	++
Sea	+++	++		+++
Air	-		+++	

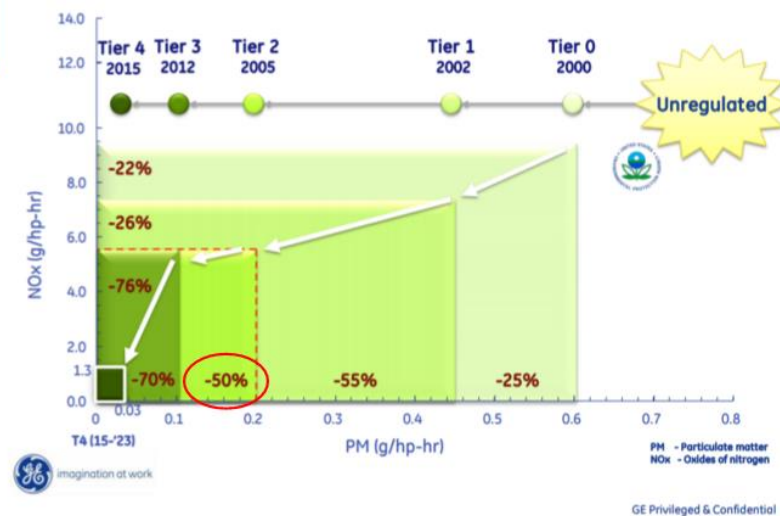
Advantages of Transportation by Sea:

- Cost efficient
- Environmentally friendly

Selection Criteria	Concepts				
	A	B	C	D	E
	Solar Roadways	Improved Fuel	(Reference) Upgraded Tier and purchase no ships	Sell trains, buy ships	Increase trucking/air
Freight throughput/capacity		0	-	0	-
Emissions/Regulatory requirements	+	+	0	+	-
Costs	-	-	0	+	-
Public Opinion	-	0	0	-	+
On time delivery	0	0	0	-	+
Sum +s	1	1	0	3	2
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Net Score	-1	-1	0	-1	-1
Rank	2	2	1	2	2
Continue?	No	No	Yes	No	No

Upgrading from Tier 2 to Tier 3 reduces the particulate matter by 50%

Locomotive EPA emissions

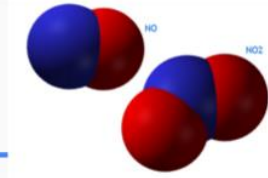


New System Emissions


Emissions of the Tier 3 Locomotives

Particulate Matter Emissions 83,800 kg  41,900 kg


Total Emissions Reduced 41,900 kg




Cost of New System

Annual fuel cost of ships  \$150 million

Assuming the miles per gallon of tier 3 is the same as tier 2:

Annual fuel cost of locomotives  \$223 million

Annual fuel costs of the new system  **\$383 million**

Savings of \$50 million by upgrading to tier 3 instead of tier 4



Benefits

115 : 1 Deaths per billion ton miles in locomotives vs. ships

242 : 1 Injuries per billion ton miles in locomotives vs. ships

3.45 : 1 pounds per ton mile of NOx in locomotives vs. ships

1 : 2.5 miles per gallon in locomotives vs. ships

Source: Iowa Department of Transportation



Prototype



Citation

United Nations Conference on Trade and Development. "World Investment Report 2010", page 56. June 2010



Questions?

VIII. Acknowledgement

As aspiring engineers, each member of the team hopes to one day develop and create solutions for societal problems. However getting to that level of professionalism in the engineering field requires a lot of hard work and ingenuity. The team would very much like to thank General Electric for providing a way for Penn State students to get their feet wet and attempt to solve real issues affecting the world today. This project gave the team the ability to think creatively and analytically. It was a rewarding learning experience and helped give a better understanding of an engineering design process.

The team of course would also like to thank Professor Xinli Wu who was supportive throughout the entire project and gave crucial guidance that led to the final design of the team's proposed new system. Xinli was able to provide inspiration and motivation for the team, which was a tremendous help to the team morale.

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