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The Pennsylvania State University
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Freight, Fuel, & Emissions

GE Transportation

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Section 002

Design Team # 5

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Daniel Gatte
Brady McDonough
Katherine Leahy
Bridget Johnson

Submitted to:
Professor Berezniak

College of Engineering
School of Engineering Design, Technology and Professional Programs
Penn State University

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Penn State University

§ **Dean, College of Engineering**
Amr S. Elnashai, FREng

§ **Department Head, SEDTAPP**
Sven Bilén, PE

§ **Course Instructor**
John Berezniak, PE

§ **Laboratory Assistants**
Keri Ford, Design LA
Michael Hoffman. Computer LA
Yamankumar Trivedi, Computer LA

GE Transportation

§ **James Bunce, Senior Manager-LNG Program**
GE Transportation
2901 E Lake Rd, Erie, PA 16531

Other Report Contributors

§ **Other Acknowledgements**
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Section 1 Executive Summary

<Enter a brief executive summary (abstract) of the report here.>

Based on the information gathered in this report, General Electric has decided to keep the locomotive transportation system, but to upgrade and replace the current technology so it fits the Environmental Protection Agency's standards, as well as being the most efficient choice financially. Locomotives will be replaced with newer Tiers, upgraded to versions that use alternative fuels, and also upgraded to include technology that will significantly reduce the emissions of the locomotive.

Section 2 INTRODUCTION

2.1 Project Objectives. Design a cost-effective solution for the Pittsdelphia freight that reduces smog, meets EPA requirements, and maintains/increases freight capacity. Assume Pittsburgh as the destination city.

2.2 Project Background. Approximately 165,000 tons of freight/materials travel via railroad per day in and out of the city of Pittsdelphia. The smog from the locomotive is becoming an issue . Tier 2 locomotives that are used are almost at the age of overhaul therefore the requirements to meet EPA Tier 3 or higher has been incorporated. Suggestions to resolve the problem are to either upgrade the locomotive or use alternate freight shipping methods.

2.3 Project Sponsor Background. GE Transportation will be the sponsor for this project. GE is well known for solving the toughest transportation issues. They are experienced with all three mining, rail, and marine industries. Their headquartered in Chicago, IL and has about 13,000 employees worldwide.

2.4 Project Description. Teams should research alternative shipping methods, evaluate, and then make a suggestion to solve the problem while keeping in mind: emissions, costs, capacity, public opinion, on time delivery.

2.5 Project Freight Requirements. Suggestions should be rationale for the recommendation, include descriptions of alternative concepts and evaluations, systems diagram, concepts of operations, environmental analysis, important aspects/public opinion, economic viability, CAD drawing (comparison slide), and a model. Assuming: (i) Mineral (coal) Transport Distance = 500 miles round-trip and (ii) Commodities Transport Distance as 1,000 miles round-trip.

2.6 Transportation Mode Comparisons.

a. Trucks. Out of all three options, trucks are the most time efficient transportation to use. Trucks are also the least expensive option. However, if there are accidents or road-work construction being completed on the shipping route the time of delivery increases greatly. This situation can usually be avoided through foresight and extended planning of alternate routes. Out of the three options, trucks hold the smallest capacity, limiting the

long term cost efficiency of the option. This form of transformation also causes pollution. Reference Figure 1 to see a typical diesel truck and trailer.

b. Barges. Barges hold a large capacity and are most environmentally friendly, offering efficiency and great public appeal. Although the public may be attracted to the low risk of damage barges pose on the environment, barges are the most expensive option and are at the mercy of the weather as ice, storms, and other forces of nature provide huge obstacles to waterway navigation. Reference Figure 2 to see Inland Waterway System, Figure 3 which includes typical locks, and Figure 4 for barges and towboats.

c. Railroad. Railroads are capable of carrying the most freight and are the most cost efficient of the three options. Railroads are also time efficient as they do not increase congestion along road or waterways, however there are choke points with limitations that currently would make passage difficult. Railroads also cause pollution and the public views them with a negative opinion due to the fact that they cause smog in the surrounding areas. Reference Figure 5-11 to see individual railroad car images.

SECTION 3 TRANSPORTATION INFRASTRUCTURE CONDITION AND CAPACITY

3.1 Introduction. Overall, Pennsylvania's infrastructure is in drastic need of repair with 7 D's, 6 C's, and 3 B's. Infrastructure updates and repairs will have to take place regardless of which mode of transportation is selected. However, roads and bridges, waterways, and rail system each suffer varying levels of disrepair.

3.2 Pennsylvania Roads and Bridges. Roads and bridges have a rating of D- and D+, respectively. The state of Pennsylvania has over 22,660 bridges, 23% of which are deficient, old, and in need of repair. Much attention has been brought to this issue and there are many efforts to remedy these issues. The problems form due to large loads in trucks putting excess strain on the bridges; this strain is inflamed by the cold conditions of winter in Pennsylvania leading to high maintenance costs. Public opinion would likely be against the additional congestion from shipping via roads and bridges, as well as the potential shipping delays from accidents, road work, and seasonal or holiday traffic. Bridges are also susceptible to floods, seismic events, and terrorist attacks. Despite these drawbacks, testing technology has advanced and bridge design software has vastly improved. The road system in Pennsylvania were rated fair or poor for 44% of roads. The roads also suffer from severe congestion and are hard to maintain for the same reasons as the bridges.

3.3 Pennsylvania Inland Waterways. The waterways of Pennsylvania are up to 150 years old, and are in severe disrepair; the waterways received an overall D+ rating. Only 18% of the waterways were satisfactory. Delays are likely and repair projects are severely underfunded, leading to a high risk of catastrophic failure, which would cripple the industries using the waterways for transport. Pennsylvania hosts 200 miles of Navigable waterways, 17 locks and dams, and the major Ohio, Allegheny, and Monongahela rivers. Despite bad conditions the port of Pittsburgh supported 35 million tons of cargo. USACE is funding a project to replace the infrastructure of the Monongahela river, but funding constraints restrict completion to after 2023. Eastern Pennsylvania could handle up to 55 million tons of freight traffic. Of the Navigable Dams, 0 are satisfactory, 7 are fair, 7 are poor, and 3 are unsatisfactory. Three locks are satisfactory, 4 fair, 4 poor, and 6 unsatisfactory. The Ohio river generally has the most delays, followed by Monongahela, but together have the largest lock.

3.4 Pennsylvania Freight Rail System. The 57 railroads of Pennsylvania have an overall B rating, the best by far of the three options, and 246 million tons of freight. However,

demand exceeds the capability. The rail system, excluding short line rails, pays for itself, improves congestion, air quality, traffic safety, and Hazard material transportation safety. Within Pennsylvania are 4 class 1 railways, 2 class 2 rails, 32 class 3 rails, and 27 local rails. Much of the freight that goes through the rail system simply passes straight through the state. Many of the short line rails run the risk of abandonment, while state rail volume is expected to grow 1.2% annually, 1.5% through freight, and 1.8% intermodal freight. Despite the favorable rating, 60% of the infrastructure is in need of rehabilitation, it has 45 traffic chokepoints, and short and regional rails are not all fit for heavy loads. There are several projects to update the railway infrastructure.

SECTION 4 STANDARD CAPACITY FOR ALTERNATE TRANSPORTATION MODES

4.1 Cargo Capacity. Reference figure 12 to see an image comparing the three forms of transportation in relation to cargo capacity. A 100-car train unit can carry the most cargo while a large semi truck carries the least. One barge falls in the middle between the two other options. To make a decision, the company must decide which option is best for them which considering safety, energy efficiency, and environmental quality.

4.2 Equivalent Units. Reference figure 12 to see an image comparing the three forms of transportation in relation to equivalent units. One barge is equivalent to fifteen jumbo hopper cars which is equivalent to fifty-eight trucks. One 15 barge tow is comparable to 2.25 100-car unit trains which can also be compared 870 large semis.

4.3 Equivalent Lengths. Reference figure 12 to see an image comparing the three forms of transportation in relation to equivalent lengths. One 15 barge tow is typically .25 miles in length which is equal to 2.25 100-car train unit that is 2.75 miles which is also equal to 870 large semis measuring 11.5 miles bumper to bumper.

SECTION 5 TRANSPORTATION COSTS AND CONCEPT OF OPERATIONS (ConOps)

5.1 Trucks. Each truck cost about $80,000-$150,000 however, if custom features are desired then the cost could rise up to $200,000. Usually the truck with better features (capacity, horsepower, fuel efficiency, etc.) are priced closer to $150,000. Aside from upfront cost, the buyer would have to factor in fuel costs, oil changes, and insurance to get a complete estimate. Transportation costs can vary widely from truck to truck. References can be found in Section 10.

5.2 Barges. There are several options with purchasing barges. An open-dry cargo hopper barge will sell for about $225,000 while a tank or liquid barge could cost about $750,000 or higher. Extra costs that would have to be covered when investing in a barge are the mooring, fuel, insurance, navigation fee, and maintenance. Not only will the overall cost include the expense for the barge and it's equipment but the buyers also have to consider the inland options, if there are any, and how expense it is to obtain an inland station. References can be found in Section 10.

5.3 Railroad. A cover hopper rail car can be purchased at $16,500. The upfront cost of the car is only one factor of the cost. There are many other expenses that come with using the railroad system. The owner also takes into account rates per ton mile for commodity rates. Maintenance is also a contributor to the cost and the control on pollutions. References can be found in Section 10.

5.4 Most Economical Transportation Solution. The most economical transportation system would be to use railroads. Considering GE is transporting a bulk item, railroads are the option to choose due to cost advantages. By using railroads instead of trucks to transport the bulk item, GE is leaving behind the issue of clearancing and permitting the use of trucks. Inventory, damage in transit, and any other material handling requirements must also be considered because they can be important and impact transportation greatly due to potentially longer transit times and travel time variability that can be experienced. Time is money therefore, railroads are the most time efficient and the best option to avoid traffic and construction.

5.5 Concept of Operations (ConOps).

a. General Description. The major system components of railroad transportation includes two major components. The first is the the rolling stock which refers to the locomotive and freight cars. The second component refers to the infrastructure. For example, the tracks, station, freight facilities, etc. The transportation system operates through several options which include a mechanical system of control, electronically, and computerized. The more common operation that is used today is computerized operation. In terms of freight operations, they are loaded and unloads in intermodal terminals.

b. Operational Policies and Constraints. The hours of operation for using railroads is 24/7, however there are constraints on staffing and the allotted time employees are given to work. There are maximum on-duty periods for each group of employees, minimum off-duty periods for train employees and signal employees. Space constraints are relative to the amount of freight cars one is using. Typically there are few issue involving space constraints on the railroad but when referring to freight facilities, space could be limited. Equipment is not too hard to find because railroads have been used for quite a long time and it is also a popular form of transportation.

c. Performance characteristics. Freight trains are regulated to use a speed of 49 mph.However, railroad work similarly to how roads work in the sense that if the weather is not so good then the speed limit will be reduce. The driver must also be conscious of when approaching curves because the speed limit is reduced. Freight capacity varies depending on the amount of cars connect but typically a rail car carries bulk items and therefore the capacity is at a high level. The US keeps striving to improve railroad systems and their reliability. Railroads are making significant investments to enhance operational efficiency, safety and communication capabilities. Due to the demand in improvement, railroads are become reliable.

d. Operational Impacts. When railroad were first used there was a huge pollution issue that not only disturbed the environment, but also the people living in the surrounding areas. Locals would walk outside and see a grey-black covering over trees, sidewalks, etc. from the smog that trains emitted. The Federal Railroad Administration reevaluated their practices and problem solved to make railroad more environmental friendly. Not only does the FRA evaluate the emissions they use, but also the hazardous materials safety, noise, invasive species, and climate change effects on the environment. They design and plan to improve these environmental effects. FRA has strongly advanced their practices overtime

and although railroads may cause pollution on the environment, it is not nearly as awful as it had been earlier in time and the continue to make improvements.

e. Continuity of Operations. To continue operations in the event of catastrophic or emergency conditions or even during extreme weather events General Electric can set up alternate routes for the railroad system. Upfront it will be more expensive to incorporate an alternate route or two but in the long term, these options could benefit the company when work must be done on one of the tracks. In terms of an extreme weather event, GE should stay clear from placing the tracks in an area close to a waterway. If a body of water were to overflow and flood the surrounding area, then our location of tracks could greatly influence our ability to continue transportation. Instead of purchasing gear for the railroads upfront to protect the the railroad car during extreme weather event, GE should plan and steer clear of potential problems. Although it may seem that building alternative rails may is more expensive for the company, it will help us to continue operation and not lose money from stopping transportation all together due to emergency conditions.

SECTION 6 EPA DIESEL EMISSION STANDARDS

6.1 Background. EPA finalized a three part program in March of 2008 that dramatically reduced emissions from diesel locomotives. The rule will cut 90% of PM emissions from these engines and 80% of NOx emissions when implemented. The standards are based on the application of high-efficiency catalytic after-treatment technology for freshly manufactured engines built in 2015 and so on. With this program, the issue of polluting the environment will slowly decline because of the incorporate of better practices. EPA has taken a great step further to solving the environmental problems of using transportation.

6.2 Tier 0-2 Standards. EPA standards for Tier 0-2 can be found in figure 13.

6.3 Tier 3-4 Standards. EPA standards for Tier 3-4 can be found in figure 13.

SECTION 7 DIESEL ENGINE EXHAUST EMISSIONS (DEEE)

7.1 Diesel Emission Chemistry.

a. NOx. - Nitrogen oxides: NOx refers to NO and NO2 specifically, and are both considered in the same group because they cycle similarly. They are hard to reduce, diesel cars emit 20x more NOx than petrol cars. Caused by the lean burning nature of diesel engines and the high T and P of combustion.

b. Particulate Matter (PM). - The sum of all solid and liquid particles in the air, many of which are hazardous. The opaque dark smoke is produced largely from spark-ignition engines. This complex mixture contains for instance dust, pollen, soot, smoke, and liquid droplets. Particles have a variety of size as well, ranging from coarse to ultrafine.

c. CO_2. - Colorless, odorless, soluble in water, and produced by combustion. Transportation is responsible for about 31% of total CO2 emissions in the US; greenhouse gas that causes global warming.

d. Hydrocarbons (HC). - Primarily come from unburned fuel; when a cold engine is started, the fuel doesn't vaporize completely. This creates HC diminishing when the engine reaches temperature. This time period can be shortened by computer-controlled fuel injection, shorter intake lengths, and pre-heating of fuel.

7.2 Diesel Emission Reduction Strategies.

- The Diesel Emissions Reduction Act (DERA) was passed in 2005. The law appropriated fund to both state and federal loan systems to either rebuild diesel engines or install emission reduction systems.
- Trucks are required to meet state emission standards, and must be retrofitted with diesel particulate filters between 2012 and 2016, with 90% required by 2014.
- Diesel particulate filters (DPF) are effective at removing 85-100%of all soot or particulate matter from the diesel exhaust of engines.

- Trucks can use on-board active systems to help filter particulates and clean the DPF, but at the expense of extra fuel consumption.
- Cordierite wall flow filters are the most common, have excellent filtration efficiency, are relatively inexpensive, and have packaging properties that make packaging them for installation simple.

7.3 Alternate Fuels.

There are 7 main types of alternative fuels: ethanol, natural gas, electricity, hydrogen, propane, biodiesel, and methanol. Of the seven different alternatives, the two most suitable for larger locomotive vehicles would be propane and biodiesel. Propane is a great alternative because it burns much cleaner and has a widespread infrastructure. It also is produced as a byproduct of oil refining and natural gas, and provides more engine power at the expense of slightly higher fuel costs. Biodiesel offers a natural and clean burning fuel alternative that can be produced in abundance from vegetable oils. As of 2007, US states such as Washington have been converting to locomotive engines that run on 75% petrodiesel and 25% biodiesel. This not only provides a much more stable source of fuel, but also a much cleaner burning source for the environment.

7.4 Human Health Issues.

- The toxic gases emitted from diesel exhaust are so small, that when we breathe it in, the hazardous particles can penetrate deep into the lungs and cause a variety of health problems.
- Can lead to cell mutations and cancer. In fact, diesel exhaust poses the highest risk of lung cancer than any other toxic air contaminant.
- Immediate health effects include eye, nose, throat, and lung irritation, leading to coughing, headaches, nausea, and even asthma attacks.
- NOx emissions can actually damage lung tissues and weaken the body's resistance to respiratory infections, and inflammation in the lungs.

SECTION 8 LOCOMOTIVE FLEET UPGRADE

8.1 Alternatives.

i. Sell existing fleet and purchase new locomotives
ii. Upgrade fleet with exhaust after-treatment hardware
iii. Utilize alternative fuels (Biodiesel, CNG, LNG, etc.) which may produce less NOx.

8.2 Existing Fleet Make-Up. {NOTE: Assume: (i) fleet consists of the following locomotives and (ii) locomotives are rebuilt at 750,000 mile intervals.}

No. of Existing Locomotives	Locomotive Group Designation	Assumed Existing Locomotive Mileage Range	Assumed Existing Diesel Type
10	A	<150,000	Tier 2
10	B	>150,000 and <300,000	Tier 2
10	C	>300,000 and <450,000	Tier 2
10	D	>450,000 and < 600,000	Tier 2
10	E	>600,000 and <750,000	Tier 2

8.3 Investment Data.

- Diesel Locomotive Upgrade
  - Tier I → Tier II
    - $750k
  - after-treatment
    - $100k
- New Locomotive
  - Tier III Locomotive
    - $3M
  - Tier IV Locomotive
    - $4M
- Alternative Fuels
  - Locomotive Upgrade
    - $1M

- Fueling Station
  - $1B

8.4 Upgrade Strategy.

Upgrading Options:

- upgrading Tier II to Tier III locomotives
- use of aftertreatment systems on Tier II locomotives
- purchasing new Tier III or Tier IV locomotives
- upgrading locomotives to use alternative fuels and upgrading fuel station

The upgrading strategy chosen for the situation is a mixture of the previous suggestions listed. Our plan is to replace all trains that have a mileage between 600,000 and 750,000 miles with Tier IV locomotives. Since these trains need to be replaced, our company decided to skip the middle man of upgrading to the tier III locomotive and jump straight to the newest, most efficient version, the Tier IV. They meet the emission requirements of the Environmental Protection Agency (EPA), so users of the locomotive won't have to worry about purchasing alternative fuels for the trains to meet the standards of the EPA. Afterall, upgrading each locomotive to use alternative fuels costs $1 million per train, as well as fueling stations that cost $1 billion. Also, the Tier IV don't require aftertreatment operations because their emissions fit within the standards of the EPA. This saves more than $1.5 billion dollars in upkeep, or infrastructure and operating costs. So, although Tier IV trains cost the most initially for replacement locomotives, they are the most cost efficient in the long run.

For efficiency purposes and to make sure goods are shipped in a speedy manner, four more Tier IV locomotives will be purchased, adding two more trains into the schedule for shipping purposes for the city. Although adding more trains to the tracks is not necessary, adding two more partners (one locomotive at each end of the cars) will drastically help the efficiency of delivery without over crowding the rails. It makes sense to purchase Tier IV locomotives because they are, initially, only $1 million more than tier III, and they save more than $1.5 billion for operation because they don't need aftertreatment. Although this costs the company money, we must take into consideration the efficiency of the the transportation system; there is always room for improvement. Over the years, more and more trains can be added to the fleet and more railways can be built, allowing more and more businesses to seek doing business with the railroad companies (bringing in more revenue this way). And because the roads have poor infrastructure ratings and waterways are almost non-existent, confiding to destinations, and have an inefficient delivery time, the the growing railroads is a smart investment; they will win the battle of transportation of goods, almost creating a monopoly for themselves, all due to their efficiency and environmental awareness, something trucks and boats simply don't have. Railroads are the only option that contain both characteristics.

Tier II trains that are replaced with Tier IV trains will be sold for a small profit once they are no longer of use.

The use of alternative fuels is important to the public, but it is not very cost efficient; upgrading a Tier II to a Tier III locomotives AND installing after-treatment systems is still less than upgrading a locomotive to use alternative fuels, not to mention the fueling stations cost one billion dollars. So, to meet the emission requirements, trains will all gradually be upgraded with after-treatment systems until they are out of mileage and are replaced by Tier IV locomotives. The Tier II locomotives (with or without after treatment) will be sold simultaneously with the purchase of the new Tier IV locomotives. However, in light of the public's demand, 60% of the money gained from selling the cars will be put to this program for the attractive alternative fuels (the other 40% will be used as profit). These fuels will also play an enormous role in cutting down on the dangerous emissions of the diesel fuel cars. The railroad company will start off with one fueling station and one Tier II upgrade to using alternative fuels.

8.5 Upgrade Schedule and Costs. <Provide tabulated cost analyses documenting the total cost of upgrading for each of the above Locomotive Groups for the existing locomotive fleet to meet EPA Tier 3-4 requirement and provide a general upgrade schedule by Calendar Year.>

5-Year Upgrade Schedule

Calendar Year	Tasks to be Accomplished	Approximated Cost, including the subtraction from the sale
2015	• replace all trains with a mileage between 600,000-750,000 with Tier IV locomotives • purchase 1 new Tier IV locomotive • sell the 10 original Tier II locomotives with a mileage between 600,000-750,000 • upgrade trains with a mileage less than 150,000 to having an after-treatment	• $43 million • *sale is negotiable; its approximated to make about $2 million*

	system	
2016	• upgrade trains with a mileage 300,000-450,000 (original group B) to having an after-treatment system • replace all Tier II trains now with a mileage between 600,000-750,000 with Tier IV models • sell the original 10 Tier II locomotives in destination with a mileage between 600,000-750,000 • purchase 1 new Tier IV locomotive	• $43 million • *sale is negotiable; its approximated to make about $2 million*
2017	• upgrade trains with a mileage 450,000-600,000 (original group C) to having an after-treatment system • replace all Tier II trains now with a mileage between 600,000-750,000 with Tier IV models • sell the original 10 Tier II locomotives in destination with a mileage between 600,000-750,000 • purchase 1 new Tier IV locomotive	• $43 million • *sale is negotiable; its approximated to make about $2 million*
2018	• all original trains have now either been updated to feature an after-	• $34 million • *sale is negotiable; its approximated to make about $10*

	treatment system or have been replaced by Tier IV locomotives • replace all Tier II trains now with a mileage between 600,000-750,000 with Tier IV models • sell the original 10 Tier II locomotives in destination with a mileage between 600,000-750,000 • purchase 1 new Tier IV locomotive	*million since they are updated with after treatment parts*
2019	• replace all Tier II trains now with a mileage between 600,000-750,000 with Tier IV models • sell the original 10 Tier II locomotives in destination with a mileage between 600,000-750,000 • upgrade the lowest-mileage after-treatment locomotive with alternative fuel features • install an alternative fuel fueling station	• $1,031,000,000 • *sale is negotiable; its approximated to make about $10 million since they are updated with after treatment parts*
2020	• replace all Tier II trains now with a mileage between 600,000-750,000 with Tier IV models • sell the 10 Tier II locomotives in destination with a	• $30 million • *sale is negotiable; its approximated to make about $10 million since they are updated with after treatment parts*

	mileage between 600,000-750,000	

*Note: Locomotives gain mileage over the year. Group A's mileage becomes that of the original group B, group B's mileage becomes that of the original group C, ect. So, the new Tier IV locomotives are taking over group A's definition of mileage. Eventually, as the trains move up in mileage, they will either be replaced by Tier IV or upgraded to after-treatment. Eventually, the after-treatment cars will be sold and replaced with Tier IV, which have no need for after treatment. Four more locomotives have been added to the fleet to improve efficiency; they are all Tier IV.

It is required by the Environmental Protection Agency (EPA) that locomotives have emissions that are off standards that are met by the minimum results of after treatment systems. However, the upkeep of after-treatment systems costs about $1.5 billion on our time scale for train mileage. Eliminating this upkeep cost would save the railroads a tremendous amount of money every year. Tier IV locomotives do not need after treatment systems to make their wastes appropriate for the environment, so their initial cost outweighs the benefit. 10 locomotives that are upgraded to the after treatment system costs $1 million, plus the additional $1.5 billion for upkeep. This number is substantially larger than simply buying a new locomotive for $4 million, with no large sum of upkeep costs. In the long run, having a fleet that is entirely Tier IV locomotives will save the railroad company a tremendous amount of money annually.

The alternative fuels are very pricey, but their use will give the company a good reputation in the public eye. Keeping up the fuel station costs about $1 billion (which is still less than the upkeep of after treatments). To make up for its cost, we can charge trains that need to use our tracks if they wish to use our fuel station. Gradually, we can transfer more of these trains into the fleet (although our data fails to give us the cost of simply buying an alternative fuel locomotive). The most cost-efficient and environmentally friendly option for this railway right now is to have a fleet of locomotives that is mainly made up of Tier IV locomotives. In the distant future, when diesel is no longer as affordable (because it has become scarce), it will be a better fit for the railroad if they transitioned into a fleet entirely consisting of locomotives that use alternative fuels.

SECTION 9 SUMMARY

To improve the transportation system of the city of Pittsdelphia, an updated railway system is the most cost-effective and efficient solution possible. Rail systems improve traffic congestion on the roads, thus reducing air pollution. They also improve traffic safety, and prove the most effective method of transport in Pennsylvania (due to their poorly-rated infrastructure and absence of major waterways that can support the size of barges). Railway cars are the least expensive compartment used for the storage of the transported goods.

The EPA standards written out in section 6 of this report are met by improved versions of locomotives on the railway. These requirements prevent dangerous diesel pollutants from harming the environment, including NOx, PM, CO, CO_2, and hydrocarbons. Alternative fuels can be used in place of diesel, and include ethanol, natural gas, electricity, Hydrogen, Propane, Biodiesel, and Methanol. Propane and Biodiesel and most often used in the railway system and prove most efficient for its source of power.

In order to improve the transportation system, we will add more locomotives to the railway system. This will put pressure on civil engineers to expand on the railways system, which we will then fill up with more cars and locomotives. In order to abide by EPA standards, there must be upgrades and replacements in the locomotives that push the cars. Locomotives that have maxed their mileage will be sold and replaced with Tier IV locomotives, the newest model; it doesn't require after treatments to produce safe amounts of emissions to the environment. Tier II cars (which the system has presently) will be upgraded with after treatment systems year after year; locomotives chosen with be Tier II's with the lowest number of miles on its mileage. One alternative fuel locomotive will be put into the fleet for good publicity and in order to please the public. In years to come, we hope that the entire fleet of locomotives of Pittsdelphia will run on alternative fuels.

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Figure 1. Typical Diesel Truck and Trailer.

Figure 2. Typical Inland Water Ways.

Figure 3: Typical Locks

Figure 4: Barges and Towboats.

Figure 5: Typical Diesel-Electric locomotive.

Figure #6: Refrigerator Car

Figure #7: Box Car

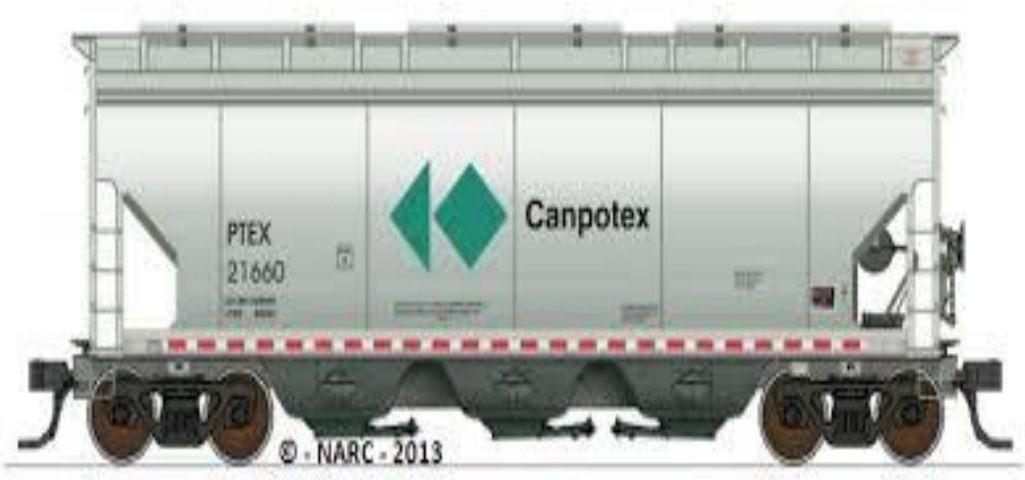


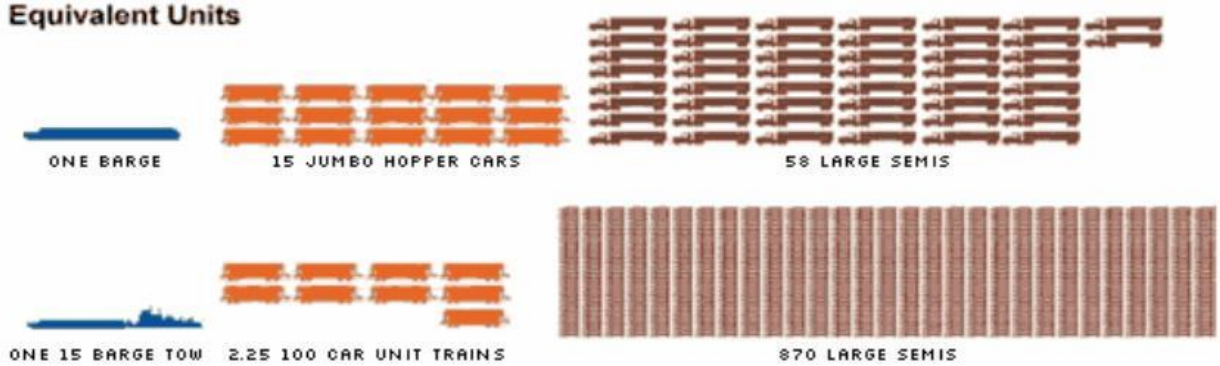
Figure #8: Hopper

Figure #9: Tank Car

Compare...

Cargo Capacity

Equivalent Units



Equivalent Lengths

Figure #10: Intermodal Railcar

Figure #11: Railcar Connectors

Figure #12. Barge vs. Truck vs. Train Comparisons

	Duty-Cycle[b]	Tier	Year[c]	HC[i] (g/hp-hr)	NOx (g/bhp-hr)	PM (g/bhp-hr)	CO (g/bhp-hr)	Smoke (percentage)[m]	Minimum Useful Life (hours / years / miles)[n]	Warranty Period (hours / years / miles)[n]
Federal[a]	Line-haul	Tier 0	1973-1992[d,e]	1.00	9.5 [ABT]	0.22 [ABT]	5.0	30 / 40 / 50	(7.5 x hp) / 10 / 750,000[o]	1/3 * Useful Life
		Tier 1	1993-2004[d,e]	0.55	7.4 [ABT]	0.22 [ABT]	2.2	25 / 40 / 50	(7.5 x hp) / 10 / 750,000[o]	
									(7.5 x hp) / 10 / -	
		Tier 2	2005-2011[d]	0.30	5.5 [ABT]	0.10[k] [ABT]	1.5	20 / 40 / 50	(7.5 x hp) / 10 / -	
		Tier 3	2012-2014[f]	0.30	5.5 [ABT]	0.10 [ABT]	1.5	20 / 40 / 50	(7.5 x hp) / 10 / -	
		Tier 4	2015+[g]	0.14	1.3 [ABT]	0.03 [ABT]	1.5	-	(7.5 x hp) / 10 / -	
	Switch	Tier 0	1973-2001	2.10	11.8 [ABT]	0.26 [ABT]	8.0	30 / 40 / 50	(7.5 x hp) / 10 / 750,000[o]	
		Tier 1	2002-2004[h]	1.20	11.0 [ABT]	0.26 [ABT]	2.5	25 / 40 / 50	(7.5 x hp) / 10 / -	
		Tier 2	2005-2010[h]	0.60	8.1 [ABT]	0.13[l] [ABT]	2.4	20 / 40 / 50	(7.5 x hp) / 10 / -	
		Tier 3	2011-2014	0.60	5.0 [ABT]	0.10 [ABT]	2.4	20 / 40 / 50	(7.5 x hp) / 10 / -	
		Tier 4	2015+	0.14[j]	1.3[j] [ABT]	0.03 [ABT]	2.4	-	(7.5 x hp) / 10 / -	

Figure #13. EPA Standards for Tier 0-4

Figure #14. Biodiesel Locomotive