The Pennsylvania State University
University Park Campus

Freight, Fuel, & Emissions

GE Transportation

EDSGN 100

Section 001

Design Team #3
Jack It Up
Fall 2015

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11 Dec 2015

ACKNOWLEDGMENTS

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Section 1 Executive Summary

Currently, the General Electric (GE) locomotive fleet for the city of Pittsburgh transports approximately 165,000-tons of freight or mineral per day. Residents of the city have been complaining about smog from locomotive emissions. GE is looking for the most efficient way to either upgrade its fleet to meet EPA standards or find alternate methods of freight and mineral shipping.

Section 2 INTRODUCTION

2.1 Project Objectives.

Pittsburgh is looking for the design of a cost-effective solution for its freight transportation that reduces smog and meets EPA requirements, while maintaining or increasing freight capacity into and out of this port city.

2.2 Project Background.

Approximately 165,00 tons of freight or mineral travel in and out of Pittsburgh each day. Smog emissions have caused residents to complain, leading General Electric to invest in locomotives that will meet EPA Tier 3 standards and allow for a cleaner environment. Possible ways of addressing locomotive emissions are:

1.) Upgrade the locomotive fleet to more recent EPA emission guidelines
    a.) Sell existing fleet and purchase new locomotives
    b.) Upgrade fleet with exhaust after-treatment hardware
    c.) Utilize alternate fuels which may produce less NO_2
2.) Alternate Freight Shipping
    a.) By Sea
    b.) By Air
    c.) By Ground, i.e. trucking

2.3 Project Sponsor Background.

Headquartered in Chicago, IL, and employing about 13,000 employees worldwide, GE Transportation works to build equipment that drives the rail, mining, and marine industries to solve the world's most pressing transportation challenges. This unit of GE produces innovative and efficient technology across various shipping industries, helping customers grow.

2.4 Project Description.

GE needs to find the most cost and environmentally effective way to either upgrade, replace, or find alternative shipping methods for its fleet. The cost, physical constraints, and fuel storage should be considered when either upgrading or replacing locomotives. Recommendations and comments should be provided on emissions, costs for fuel and infrastructure, freight capacity, the public opinion, and punctual delivery for each mode of transportation. After considering all of the variables for the different delivery methods, a

general plan should be developed for the most effective cargo delivery method to the city of Pittsburgh.

2.5 Project Freight Requirements.

The city of Pittsburgh currently moves approximately 165,000 tons of freight per day. There are 15 trains used per day which consists of 3 mineral trains and 12 freight trains. The mineral trains move 12,000 tons of coal per train and the freight trains move 7,000 tons of freight/intermodal. These trains require diesel, currently at a price of $3.06 per gallon, to operate.

2.6 Transportation Mode Comparisons.

a. Trucks.

Trucks are widely used by companies across the nation to transport goods long distances. The advantage to this method is that it is the most inexpensive when compared to ships, trains, and planes. The disadvantages are that trucks are slow, have a small cargo capacity, and are not environmentally friendly. A large semi-truck would be used for the trucking method of shipping. A large semi has a carrying capacity of 26 tons, 910 bushels, or 7,865 tons. It carries an amount equivalent to 1 barge or 15 jumbo hopper train cars. Figure 1 adequately depicts a typical Truck and Tractor Trailer.

b. Barges.

A barge is a large vessel that is used to transport freight across waterways. Since a barge is unable to move on its own, it needs assistance from another boat to move it from place to place. The most common type of boat is used is the tugboat. A typical barge and tug boat are depicted in Figure 2. One large disadvantage is the length of time required to move freight between locations. Some advantages are that it is cheap to operate, it is able to move large amounts of freight, and is also environmentally friendly. These tugboats and barges operate on the U.S. Inland Waterways System. The Inland Waterways system includes 12,000 miles of commercially navigable channels and some 240 lock sites.

c. Railroad.

Rail shipping is the most effective overall whensimultaneously considering cost, capacity, time, and environmental variables. Trains consist of one or more locomotives and various rail cars. Rail transportation is the second most cost effective behind sea transportation as well as the second most environmentally friendly. The main advantage to rail transportation is that it has the highest cargo capacity; one disadvantage is that it is not extremely time efficient. Boc, Hopper, Refrigerator, and Oil Tank cars are different options

for rail cars. GE would most likely choose the Hopper Car in Figure 4; however, Figures 3, 5, and 6 clearly show other options for their cargo.

SECTION 3 TRANSPORTATION INFRASTRUCTURE CONDITION AND CAPACITY

3.1 Introduction.

The 2014 Report Card for Pennsylvania Infrastructure details the current situations of bodies of water, roads, bridges, and electricity. The report shows where our state infrastructure currently is and where it should be according to state legislature. It provides information to the general public about the place they live in and how it's holding up. The report is published by the American Society of Civil Engineers (ASCE). Relevant infrastructures grades are as follows: Bridges received a D+, Inland Waterways received a D+. Ports received a C+, Transit earned a D, Roads got a D-, and Freight Rail received a B. These grades are based on current facilities, needed improvements, future outlook, percent deficient, and other factors.

3.2 Pennsylvania Roads and Bridges.

Pennsylvania's roads and bridges are both in poor condition, with each receiving a D- and a D+ respectively on the report card. Twenty-three percent of bridges in Pennsylvania are considered structurally deficient; the highest percentage in the nation. Figure 7 shows a typical bridge in Pennsylvania. These bridges are very old and repair is needed. While these bridges desperately need to be fixed, closing them would negatively impact traffic flow and the economy of certain regions of the commonwealth. The roads are in even worse shape, with 44% needing repairs. This need is influenced heavily by the heavy truck traffic on interstate roads. As seen in Figure 8, this continual traffic has caused severe infrastructure damage. Building more roads and increasing the number of lanes would decrease traffic and improve driving conditions for all commuters. Currently there is insufficient funding for bridge and road improvements, even with legislation from the state adding money to the budget.

3.3 Pennsylvania Inland Waterways.

The Pennsylvania inland waterways received a D+ in the report card for Pennsylvania infrastructure. Due to it being built over the past 100 years, many of the dams and locks

are in a severe state of disrepair. About 18 percent of the locks have received a satisfactory grade in bridge condition. These unsatisfactory and unacceptable conditions lead to delays in shipping of cargo across the waterways.

3.4 Pennsylvania Freight Rail System.

Pennsylvania has the 4th largest rail network by mileage in the U.S. with 57 freight railroads covering 5,127 miles across the state. According to estimates, a 22 percent increase in tons of freight passing through the Commonwealth of Pennsylvania is expected by 2035. However, the demand on Pennsylvania's railroad freight demand continues to exceed current infrastructure. Railroad traffic is steadily increasing and will surely provide problems in the near future. Projects to solve future problems that will be necessary to undertake will cost the Commonwealth approximately $280 million. Annual state-of-good-repair track and bridge expenditures for all railroad classes within the Commonwealth are projected to be approximately $560 million. A typical Freight Car can be seen in Figure 9. Class I railroads, the largest railroad companies, are poised to cover their own financial needs; however, some smaller railroads need assistance to continue service to rural areas of the state. Pennsylvania has 4 Class I, 2 Class II, 32 Class III, and 27 local railroads.

SECTION 4 STANDARD CAPACITY FOR ALTERNATE TRANSPORTATION MODES

4.1 Cargo Capacity.

In terms of cargo capacity, one 15 barge tow is the best method for shipping and one highway truck trailer is the worst. The 15 barge tow can carry 22,500 tons while the truck trailer can only carry 26. In between falls one barge, carrying 1,500 tons, and the rail methods for shipping. One boxcar type railroad car carries 100 tons and one bulk type carries 10,500 tons. This all is clearly shown in Figure 10.

4.2 Equivalent Units.

One barge requires fifteen jumbo hopper cars to equal its capacity, or in other terms fifty-eight large semi-trucks. Going further, eight-hundred large semis would not be efficient compared to one 15 barge tow or 2.25 one-hundred car unit trains. Pictured and the end of this report, Figure 11 accurately depicts the equivalence of units between these modes of transportation.

4.3 Equivalent Lengths.

One 15 barge tow has a total length of 0.25 miles when placed bow to stern. A 2.25 100 car train unit has a total length of 2.75 miles. The 870 large semis have a total length of 11.5 miles when placed bumper to bumper. Figure 12 clearly depicts these comparisons.

SECTION 5 TRANSPORTATION COSTS AND CONCEPT OF OPERATIONS (ConOps)

5.1 Trucks.

With truck transportation, several related costs factor into the overall cost. One universal cost is diesel fuel, which most trucks use. Currently, diesel fuel is about $2.50, which is about $1.20 less than 2014. And before that, between 2011-2013, the price per gallon hovered around the $4.00 mark. Besides gas, there are many other costs. This includes Truck Lease, Repair and Maintenance, Truck Insurance, Permits and Licenses, Tires, Tolls, Driver Wages, and Driver Benefits. Taken from data in Figure 13, transporting goods costs about $1.676 per mile. This table includes every cost that goes into transporting good via trucking. Also, between 2008 and 2013, the average cost per mile, $67.00, stayed very constant. Another way to look at costs of shipping goods via trucking is by the hour. Based on the data collected by American Transport Research Institute in Figure 14, the cost per mile and per hour, and how it is broken down for the trucking industry, is shown clearly.

5.2 Barges.

Calculating transportation costs for barges is slightly more complex than for road, rail, or air transportation. There are two ways companies typically set rates for barge

transportation. Some charge on a dollars per ton basis for dry bulk, with a minimum tonnage required. Others charge by dollars per barge load, a flat rate with no tonnage requirement. The average cost of moving cargo by barge in the Port of Pittsburgh district ranges between $.005 and $.01 per ton mile of cargo moved.

5.3 Railroad.

Transporting goods by rail is typically a cheap method with the typical rate being $0.03 per ton-kilometer. This is because the fuel for trains is cheaper than the trucking counterpart. Fuel costs are only 25 percent of the rail costs. Most of the expenses of the railroads include initial costs and periodic maintenance. Therefore, continuous transporting would not be costly because the railroad transportation does not require much upkeep and is fuel efficient. Also, for every locomotive, one engineer and one conductor need to be hired. Generally railway transportation provides relatively time efficient arrival as well as providing inexpensive freight transportation rates.

5.4 Most Economical Transportation Solution.

The most economical transportation system is a combination of both trains and barges. Based clearly on the chart in the GE Presentation, these two transportation methods are the best options when taking into consideration carrying capacity, speed, cost, and environmental standards. Group E of Pittsburgh's fleet of trains should be replaced by barges in shipping the cargo, while the rest of the fleet will be either upgraded or replaced with new locomotives.

5.5 Concept of Operations (ConOps).

a. General Description.

The combination system of sea and rail transportation will be much more efficient, as well as environmentally friendly, than the fleet of trains currently in use. The sea aspect of the new system will transport cargo that is currently being shipped by the fleet's Group E locomotives. Locomotive Groups A and B will be upgraded to meet EPA standards and then after treatments will be applied. In addition, Tier 3 locomotives will be purchased to replace current Group C and new Tier 4 locomotives will replace Group D. There are ten locomotives per group and the classifications for these groups can be found in section 8.2. The trains will continue to operate on existing rails with some modifications made to accommodate the size of upgraded locomotives. The new barges will operate on various inland waterways to transport cargo.

b. Operational Policies and Constraints.

Another beneficial aspect of this transportation system is that both methods of shipping can operate past regular business hours and require limited crew. Both trains and barges can travel overnight which is extremely useful to move cargo over fewer business days. While barges require a larger crew than locomotives, essentially the same number of people will be getting paid due to the fact that there will be less locomotives to staff. One logistical issue is that barges may not be able to go to the same destinations that trains can. This is compensated for, however, by the fact that trains will no longer need to go to places that barges can - therefore the movement of cargo will balance itself out. A constraint that comes along with the upgraded locomotives is that the new equipment makes the train too large to fit through some tunnels. This can easily be remedied by sending those trains on routes not dependent upon tunnels. Also, frequently used rail infrastructure could be remodeled to allow the upgraded locomotives to travel freely on popular routes.

c. Performance characteristics.

Based on the chart in the GE Presentation that compares the time, cost, capacity, and environmental effects of air, truck, rail, and sea shipping methods, it is clearly determined that barges are largely more efficient than trains. They can transport more cargo, have less expensive shipping costs, and are safer because they travel on the less crowded sea. Along with that, barges are much more reliable as they are much more independent than trains. Trains depend on the railroads to be operational in order to ship. If there would be damage to a section on a railroad, it would need to be fixed before the cargo could be shipped on that railroad. With barges, as long as no major river is somehow unsafe, barges will operate more reliably than trains. However, it does take longer to get the cargo from one point to another using barges. With both barges and trains having distinct advantages, a combination of both transportation methods would help save time, money, and keep the environment clean while operating at a highly efficient rate.

d. Operational Impacts.

By adding in a set of barges to transport our cargo, a cleaner system for shipping is created. Based on the chart in the GE Presentation, it clearly shows that sea shipping is very environmentally friendly which makes the local population very happy. This also cuts down on air pollution from trains as there are less trains running and therefore automatically lower pollution levels generated. The trains have also been upgraded to meet or exceed the new EPA Tier 3 standards or been replaced by such trains. This collective cutting down on EPA emissions will lead the local population to be pleased with GE's changes, and will positively help the Earth moving forward.

e. Continuity of Operations.

One advantage of having two very different methods of shipping is that in case a natural disaster should happen on land such as a tornado or earthquake, it would still be possible to ship cargo to Pittsburgh via barges. On the other hand, if the rivers used to transport our goods somehow become inadequate, like if an unusually high amount of water evaporated due to increasing temperatures and the rivers were not deep enough for the barges to travel through, the trains would be reliable enough to transport our cargo. This division of transportation methods helps plan for the unexpected and keep operations running in the case of emergencies.

SECTION 6 EPA DIESEL EMISSION STANDARDS

6.1 Background.

In 1998, tier standards 0, and 1 were proposed, and were to be effective starting January 2000 to January 2005 and later adopting newer standards. Tier 0 standards intended to generate about one third less NO_x and PM emissions from the uncontrolled levels. Tier 0 standards were argued to be both too stringent and lenient, because of the availability of the locomotive reduction technology and not cutting back enough emissions and increasing fuel costs and other emissions respectively. Tier 1 standards were designed to reduce PM and NO_x emissions from about half of the uncontrolled levels. Tier 1 standards were more stringent than Tier 0 but were still argued that the standards are above an uncontrolled baseline. Tier 2 was also introduced with a sixty to sixty-five percent cut of emissions from uncontrolled levels. EPA announced and proposed that the levels could be achieved through improvements in air cooling, fuel management, the combustion chamber, and electronic control systems. Generally, Tier 0 and Tier 1 standards were feasible for the early 2000s while Tier 2 was argued not to be, but it was also argued that all tiers could be more stringent. In 2005, the ideas of Tier 3 and 4 standards were proposed to cut emissions about 70 to 75 percent and to almost no emissions respectively. 2005 mainly focused on what types of vehicles and engines could meet each tier with the available technology. As the years progressed, 2008, 2010, and 2011, the main focus was to progressively improve the tiers of engines through either new manufacturing or remanufacturing different locomotives and improving various individual structures or

features. The ultimate goal of the EPA is to reduce emissions as much as possible from locomotives.

6.2 Tier 0-2 Standards. The Tier 0 EPA standards is between 0.45 and 0.6 PM (g/hp-hr) and between NOx 6.7 and 8.8 (g/hp-hr). It has a percentage of -22 percent. The Tier 1 EPA standards is between 0.2 and 0.45 PM (g/hp-hr) and between 4.6 and 6.7 NOx (g/hp-hr) the tier 1 - 2 has a percentage of -26 percent.

6.3 Tier 3-4 Standards. The Epa standards for a Tier 3-4 train is between 0.1 and 0 PM (g/hp-hr) and between 0 and 4.6 NOx (g/hp-hr). The tier 3-4 has a percentage of -76 percent.

SECTION 7 DIESEL ENGINE EXHAUST EMISSIONS (DEEE)

7.1 Diesel Emission Chemistry.

a. NOx.

Nitrogen Oxides (NOx) are a family of highly reactive poisonous gases. These gases form from burned fuel at high temperatures. NOx pollution is emitted by automobiles, trucks and other non-road vehicles as well as industrial sources such as power plants, industrial boilers, cement kilns, and turbines. Nitrogen Oxides typically appear as brownish gas. It is a strong oxidizing agent and plays a major role in the atmospheric reactions with volatile organic compounds that produce smog on hot summer days.

b. Particulate Matter (PM).

Particulate Matter is a complex mixture of extremely small particles and liquid droplets. PM is made up of a number of components including organic chemicals, metals, acids, and soil or dust particles. The size of particles is directly linked to their potential for causing health problems. EPA is concerned about particles that are 10 micrometers in diameter or smaller because those are the particles that generally pass through the throat and nose and enter

the lungs. Once inhaled, these particles can affect the heart and lungs and cause serious health effects.

c. CO_2.

Carbon dioxide (CO2) is the primary greenhouse gas emitted through human activities. The main human activity that emits CO2 is the combustion of fossil fuels (coal, natural gas, and oil) for energy and transportation, although certain industrial processes and land-use changes also emit CO2.

d. Hydrocarbons (HC).

Hydrocarbon emissions result when fuel molecules in the engine do not burn or burn only partially. Hydrocarbons react in the presence of nitrogen oxides and sunlight to form ground-level ozone, a major component of smog. Ozone irritates the eyes, damages the lungs, and aggravates respiratory problems. A number of exhaust hydrocarbons are also toxic, with the potential to cause cancer.

7.2 Diesel Emission Reduction Strategies.

There are several diesel emission reduction strategies which are highly effective. First, there are engine modifications that can be performed on older engines that produce the most emissions. The diesel combustion process itself is altered, however this is no simple task because reducing one type of diesel emission tends to increase another. A balance must be found and it can be reached in a variety of ways: combustion cylinder alterations, delaying the start of fuel injection, recirculating exhaust gas back into the engine, and various methods which directly change the combustion reaction. Second, there are exhaust control technologies, such as oxidation catalysts, which can be used in conjunction with engine modifications. Third, there are new formulas for fuel, and alternative fuel options, that could be used more widely to reduce emissions. These strategies have been proven to benefit the environment.

7.3 Alternate Fuels.

There are numerous alternative fuels. Diesel is not the only option for trains to use for power. Some of the most common alternative fuels are: biodiesel, electricity, ethanol, hydrogen, natural gas and propane. Biodiesel is a renewable source of fuel than can be created from oils and animal fats. Electricity is everywhere and the advancement of electric batteries and motors will greatly increase efficiency. Ethanol is also a renewable source of

fuel that is derived from corn and other plants. Hydrogen is highly abundant in the air, and will have no harmful byproduct after being used as fuel. Natural gas is abundant in the US and is more efficient and cost effective compared to gas and diesel. Propane is also abundantly found across the US and has been used by vehicles for numerous years. All of these fuels have different advantages over the more commonly used gas and diesel.

7.4 Human Health Issues.

Although diesel engines are cheaper to run than gas engines, they do pose a threat on human health. Diesel emissions are composed of a variety of different chemicals and can include cancer causing ones such as benzene, arsenic, and formaldehyde. Human exposure to diesel emissions is inevitable because it is widely used; air, regardless of the setting, contains some amount of the substances. Risk of health problems and exposure is increased if someone is working or living near frequently used diesel equipment. The toxic gases breathed in from diesel emissions contain particles that are large enough to penetrate the lung and possibly cause cell mutations leading to cancer. There are also immediate health effects when exposed such as eye, nose, throat, and lung irritation, as well as coughing, lightheadedness, headaches, and nausea. The elderly or people with asthma, emphysema, or chronic heart and lung disease can be more sensitive to the diesel particle pollution, increasing their health risks. As it is the same with all equipment that burns fuel, nitrogen oxides are released that are popular in damaging lung tissue and causing a variety of lung diseases. Overall the emissions of diesel fuel pose a threat on human health, mainly the lungs and breathing.

SECTION 8 LOCOMOTIVE FLEET UPGRADE

8.1 Alternatives.

i. Sell existing fleet and purchase new locomotives

Selling and buying new fleets is one of the most costly methods of improving diesel emissions, yet it is also the most effective way. The revenue of selling tier 2 locomotives is unknown, but there is some type of income for selling the existing locomotives. Prices vary when buying entirely new locomotives because either a tier 3 or tier 4 locomotive can be

purchased. To buy a tier 3 locomotive it would cost three million dollars for a single locomotive; it would cost four million for a tier 4 locomotive. It would be most logical to purchase new locomotives for the tier 2 locomotives that have the most miles on them, while upgrading locomotives to tier 3 with the least miles. If all of the existing locomotives are replaced with new models, the number of tier 3 and 4 locomotives would be based on a budget and public opinion of diesel emissions.

ii. Upgrade fleet with exhaust after-treatment hardware

As the cheapest option, upgrading the fleet from tier 2 to tier 3 with after treatment costs would significantly reduce diesel emissions, but most likely not enough for the public because there would be no tier 4 locomotives. In order to upgrade a tier 2 locomotive to tier 3 it would cost $750 thousand to upgrade the individual locomotive, but there is also an after-treatment cost of $100 thousand. It would cost around $850 thousand to upgrade each locomotive from tier 2 to tier 3 which is extremely cost effective compared to the other methods of diesel emission reduction yet does not provide the most environmentally friendly option. Each locomotive would reduce emissions from 50% to about 70%, going from unregulated standards of tier 2 to tier 3 respectively. The public wants the locomotives to be mostly tier 4 because it nearly cuts all exhaust emissions from the unregulated standards therefore upgrading to all tier 3 would not be in the favor of the public compared to other options.

iii. Utilize alternative fuels (Biodiesel, CNG, LNG, etc.) which may produce less NOx.

The most overlooked option but also the most expensive would be using an alternative fuel for the locomotives such as natural gases. GE introduced NextFuel Natural Gas Retrofit Kit which is the use of liquefied natural gas. The kit substitutes about 80% of gas along with a 50% reduction in fuel costs. GE's NextFuel is only one option of using an alternate fuel as there are other fueling options. In order to upgrade a single locomotive so it can run on an alternate fuel it would cost one million dollars per locomotive which is not nearly as expensive as replacing the existing fleet, but the drawback is that there has to be a one billion dollar fueling station installed for the alternate fueling. Economically, using an alternative fuel method is not the most ideal when compared to the other methods of diesel fuel emission reduction. In the long run, using an alternative fuel and investing in installing a fueling station could be worth it because it can reduce fueling costs up to 50% but if it is possible to buy tier 4 locomotives for four million dollars each then that would be more ideal in the short run.

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.

Currently there are 50 Tier 2 trains. To upgrade these trains to a tier 3 locomotive would cost roughly 750,000 for the upgrade and 100,000 for the after-treatment. To purchase a new Tier 3 train would cost $3 million and a new tier 4 train would cost $4 million. To change the locomotives fuel that they operate on would cost about $1 million to upgrade the train. The new trains would need new fueling stations and these stations would cost around $1 billion to construct.

8.4 Upgrade Strategy.

To upgrade the existing locomotive fleet to meet the EPA Tier 3-4 requirement, many different approaches must be considered in order to effectively and economically solve the problem. One possible solution would be to upgrade all current locomotives from Tier 2 to Tier 3. This would cost $750,000 for each upgrade. Also, an after-treatment cost must be accounted for with each upgrade, which would be an additional $100,000. Another strategy would be to sell the entire existing fleet and purchase new Tier 4 locomotives at $4 million each. It is also possible to buy Tier 3 locomotives at $3 million each to avoid the after-treatment cost. The strategy taken was a combination of these options. First, it was decided to upgrade groups A and B because of their low mileage. This low mileage means that they still have plenty of years left of transporting cargo efficiently and therefore do not need to be replaced. Next, group C replaced with Tier 3 locomotives. Subsequently, the unneeded and heavily used cars will be sold. Buying Tier 3 locomotives effectively replaces the group C cars while meeting the standards and avoiding the after-treatment costs. With Tier 4 locomotives being the ideal locomotive that residents prefer, it was decided to upgrade the last two groups, D and E, to Tier 4 locomotives by selling the existing fleet and purchasing brand new Tier 4 locomotives. While these cost more than new Tier 3 locomotives, they make the general public happier while also being more gas-efficient.

We also came to the conclusion early that alternative fuels would be unnecessarily expensive and illogical. The $1 billion cost of the fueling station along with the upgrade cost of $1 million for each different type of fuel proves to be inefficient and unnecessary.

8.5 Upgrade Schedule and Costs

Between groups A and B, there are 20 locomotives that need to be upgraded to Tier 3 locomotives; this will cost $750,000 dollars per locomotive, adding up to a total cost of $15 million. Additionally, there are after treatment costs associated with each locomotive that is upgraded. The $100,000 after treatment for each locomotive accumulates to another $2 million. Group C of the fleet will be upgraded to $3 million Tier 3 locomotives, for a total of $30 million. Lastly, the 20 locomotives in Groups D and E will be upgraded to new $4 million Tier 4 locomotives, costing a total of $80 billion. These upgrades will be made in increments of one group per year over the course of five years. Throughout the calendar year, one locomotive will be upgraded or replaced essentially each month.

SECTION 9 SUMMARY

Through this project, it has been determined that air, truck, rail, and sea shipping each provide different advantages for General Electric. However, it has become clear that rail and sea shipping are the most efficient when used together.

With 50 Tier 2 locomotives ranging in usage from brand new to very old, General Electric (GE) has to upgrade its entire fleet to meet the new standard EPA emissions. It is now required that all trains be at least a Tier 3 locomotive, or the brand new Tier 4 locomotive. The advantages to Tier 4 locomotives are that they are more environmentally friendly and fuel efficient. However, they are more expensive than the Tier 3 locomotive. In order to meet these standards, GE can upgrade current Tier 2 locomotives or buy new Tier 3 or Tier 4 locomotives. Upgrading is less expensive, but new trains will last longer and be more fuel efficient. With this knowledge, it is best to upgrade the newest locomotives while completely replacing the oldest locomotives.

Sea shipping also can benefit GE. By replacing the most used group of locomotives with its equivalent in barges and tugboats, GE will save money and become more efficient. Overall, the most efficient solution to GE's problem is to upgrade Group A and B to Tier 3 locomotives, replace Group C with new Tier 3 locomotives, replace Group D with Tier 4 locomotives, and replaced Group E with barges and tugboats.

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- http://waterwayscouncil.org/waterways-system/

Figure 1. Typical Diesel Truck and Trailer.

<Insert all of your Figures starting here. >
<NOTE: All Figures must have a Figure Number and Title and be referenced from a Section of the Report. Only one Figure per page.>

Figure 2. Typical Inland Waterways Barge and Tug.

Figure 3. Typical Box Car.

Figure 4. Typical Hopper Car.

Figure 5. Typical Refrigerator Car.

Figure 6. Typical Oil Tank Car.

Figure 7. A Typical Bridge in Pennsylvania.

Figure 8. Typical Vehicular Traffic on Pennsylvanian Roads.

Figure 9. Typical Freight Car.

Figure 10. Comparing Cargo Capacity of Transportation Methods.

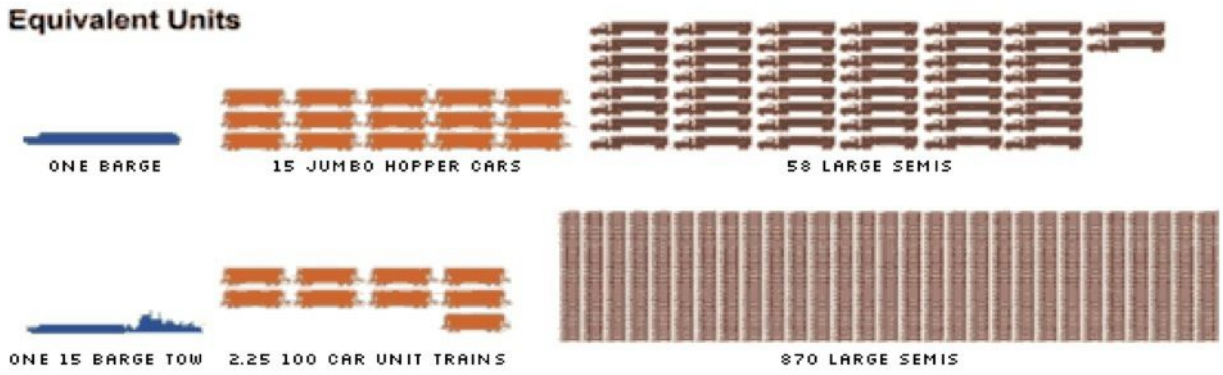

Figure 11. Equivalent Units of Transportation Methods.

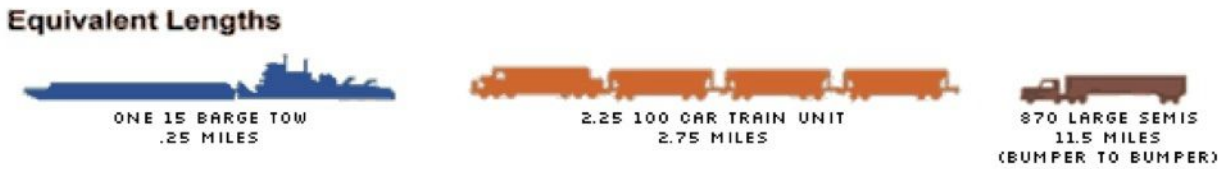

Figure 12. Equivalent Lengths of Transportation Methods.

Motor Carrier Costs	2008	2009	2010	2011	2012	2013
Vehicle-based						
Fuel Costs	$0.633	$0.405	$0.486	$0.590	$0.641	$0.645
Truck/Trailer Lease or Purchase Payments	$0.213	$0.257	$0.184	$0.189	$0.174	$0.163
Repair & Maintenance	$0.103	$0.123	$0.124	$0.152	$0.138	$0.148
Truck Insurance Premiums	$0.055	$0.054	$0.059	$0.067	$0.063	$0.064
Permits and Licenses	$0.016	$0.029	$0.040	$0.038	$0.022	$0.026
Tires	$0.030	$0.029	$0.035	$0.042	$0.044	$0.041
Tolls	$0.024	$0.024	$0.012	$0.017	$0.019	$0.019
Driver-based						
Driver Wages	$0.435	$0.403	$0.446	$0.460	$0.417	$0.440
Driver Benefits	$0.144	$0.128	$0.162	$0.151	$0.116	$0.129
TOTAL	**$1.653**	**$1.451**	**$1.548**	**$1.706**	**$1.633**	**$1.676**

Figure 13. Average Marginal Costs per Mile via Trucking.

Motor Carrier Costs	2008	2009	2010	2011	2012	2013
Vehicle-based						
Fuel Costs	$25.30	$16.17	$19.41	$23.58	$25.63	$25.78
Truck/Trailer Lease or Purchase Payments	$8.52	$10.28	$7.37	$7.55	$6.94	$6.52
Repair & Maintenance	$4.11	$4.90	$4.97	$6.07	$5.52	$5.92
Truck Insurance Premiums	$2.22	$2.15	$2.35	$2.67	$2.51	$2.57
Permits and Licenses	$0.62	$1.15	$1.60	$1.53	$0.88	$1.04
Tires	$1.20	$1.14	$1.42	$1.67	$1.76	$1.65
Tolls	$0.95	$0.98	$0.49	$0.69	$0.74	$0.77
Driver-based						
Driver Wages	$17.38	$16.12	$17.83	$18.39	$16.67	$17.60
Driver Benefits	$5.77	$5.11	$6.47	$6.05	$4.64	$5.16
TOTAL	**$66.07**	**$58.00**	**$61.90**	**$68.21**	**$65.29**	**$67.00**

Figure 14. Average Marginal Costs per Hour via Trucking.