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GE Transportation

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SECTION 1 EXECUTIVE SUMMARY

GE Transportation, a unit of GE (NYSE: GE), solves the world's toughest transportation challenges. One of those challenges is to find viable business strategies for furthering the transportation industry when given new regulations. The company has a fleet of Tier II locomotives that either need to be upgraded to Tier III or sold and replaced by other locomotives or alternative forms of transportation. Research was done to decide which option was most viable economically, environmentally, and ethically.

SECTION 2 INTRODUCTION

2.1 Project Objectives. Trucks and barges that carry freight to the city of Pittsburgh omits smog into the air. Pittsburgh is looking for a design of a cost-effective solution that can reduce the amount of smog emitted but a solution that also meets EPA requirements. This design must also maintain and increasing freight capacity that comes into and out of this important port city.

2.2 Project Background. Approximately 165,000 tons of freight and minerals (coal) travel via railway into and out of Pittsburgh. A major complaint that generates amongst the city's residences is the large amount of smog these locomotives emit. Smog is created from engine-emitted NOx, atmospheric pollutants. Tier two locomotives that are usually used to carry freight are becoming less reliable to use to haul. This problem then requires an investment to meet EPA Tier three requirements. Some suggestions have been made to reduce the amount of smog emitted, these suggestions include:

1. Upgrade the locomotive fleet to meet recent emission guidelines set by the EPA (sell existing fleet, upgrade fleet, and utilize alternate fuels)
2. Alternate freight shipping methods (sea, air, ground)

2.3 Project Sponsor Background. This project is sponsored by General Electric (GE) Transportation. GE is a company known for creating greener/ environmentally friendly and energy efficient systems. GE is headquartered in Chicago, IL and have over 65 sites worldwide. In 2014 alone GE and their partnerships had a $5.7 billion profit.

2.4 Project Description. Each design team will research different options for the suggestions made for either a fleet upgrade or an alternate shipping method. Teams should consider physical constraints of new hardware as well as fuel storage requirements concerning upgrades. Teams will also provide their recommendations on emissions/ regulatory requirements, costs (i.e. fuel, infrastructure), freight throughput/ capacity, public opinion and on time delivery.

2.5 Project Freight Requirements. In the SOW we were given some freight data. The freight data included in the Statement of Work included that there are 20 trains per day, made up of 5 mineral trains and 15 freight trains. The project also required that the mineral (coal) round trip has to be close to 500 mile round-trip. Due to this requirement we chose to have Huntington, OH as our starting destination because by water it is approximately 250 miles one way. Also the commodities transport total distance is 1,000 miles round-trip.

2.6 Transportation Mode Comparisons.

a. Trucks. The trucks that we will be discussing are semi-trailer trucks, also known as eighteen wheelers. Semi-trailer trucks are a combination of a tractor unit and one or more semi-trailers to carry freight. The semi-trailer attaches to the fifth wheel hitch of the tractor unit. These trucks typically have two to three axles. Trucks require larger breaking forces so they use air pressure rather than hydraulic fuel. These trucks also have a manual transmission to allow the driver as much control as possible. Some disadvantages of using trucks include they are not very cost effective and they don't have space for large capacity's. One advantage of trucks is that they have one of the fastest delivery time. A typical truck with trailer is located in the figures section and is titled Figure One.

b. Barges. A barge is a flat-bottomed boat built mainly for the transportation of heavy goods through rivers and canals. A standard barge is usually 195 ft. long and 35 ft. wide, and can hold up to 1,500 tons of weight. The barges that we will be describing will be driving through the Inland Waterway System. The Inland Waterway System have commercially important waterways it expands from Pittsburgh all the way to Mississippi. A map of the Inland Waterway System is below as Figure 11. When the barges are not in use they are stored in barge locks located on the body of water, reference Figure Ten to see a typical barge lock. Barges are used to transport low value bulk items due to the very low costs for transportation. Barges have other advantages as well including that its environmental friendly and it can hold large capacities of goods. One downfall to barges is that they do not deliver goods in the fastest amount of time. Barges have a pretty simplistic design and a picture of what they look like is located below as Figure Nine.

c. Railroad. Freight trains are one or more locomotives connected to transport goods along a railroads. Trains can haul different goods including bulk material, intermodal containers, general freight or specialized freight. Typical freight trains today can reach up to 14,000 feet long. Each individual train is connected with a hinge system. There are several advantages of using the railroad to transport goods. Trains can haul large amounts of goods, they are also somewhat cost effective, and are also somewhat environmentally friendly. Unfortunately they are not as time efficient as trucks but they are faster then moving by barges. There are multiple types of railroad cars including hoppers, refrigerator cars, box, cars, intermodal cars, tank cars, flat cars, etc.. Pictures of typical freight trains and railroad cars are listed below as Figure Three, Four, Five, Six, Seven, and Eight.

SECTION 3 TRANSPORTATION INFRASTRUCTURE CONDITION AND CAPACITY

3.1 Introduction. The Pennsylvania Sections of the American Society of Civil Engineers (ASCE) provide a yearly report card of Pennsylvania's Infrastructure so that each citizen can understand how well Pennsylvania's Infrastructure is doing.[1] In the 2014 report card on Pennsylvania's Infrastructure shows that the leaders have made big changes to improve immediate and long-run infrastructure needs of the Commonwealth.[1] The report card includes grades for bridges, dams, drinking water, energy, etc. Many of the grades given to these items are C's and D's, Pennsylvania Infrastructure has received very few B's.

3.2 Pennsylvania Roads and Bridges. The rating of the roads and bridges in Pennsylvania conducted by the ASCE reveal that for such highly traveled roads and bridges, their infrastructure is far from being up to par. Bridges received a rating of D+, while roads received a rating of D-. Though this does not make them unsafe to travel on, it does indicate that they are in very poor conditions, and need much improvement. Reportedly, of the 22,600 bridges located in Pennsylvania, 23 percent have been found to be deficient. Even with the funding that will be put into full effect in 2019, there will not be enough funding to pay for the renovations that will need to take place for about 40 percent of the bridges. The problems that we face in having to fix the bridges and roads, also impact the capacity of the roadways. The capacity of bridges are down 21.8 percent from that of 2001 (indicated in Figure 13). This decline will continue if the lack of funding is not addressed. This is a difficult problem to address due to the fact that there is a need for more lanes, to increase capacity on the road, and the closure of bridges for maintenance will cause an increase in congestion on the roadways, as well as cause a decline in the economy. Figure 14 listed below is a picture, provided by PennDOT which, analyze the conditions of the roads, and shows that as time passes the condition of roads are not increasing, and a lack of funding.

3.3 Pennsylvania Inland Water Ways. Pennsylvania inland waterways are no exception to the poor school reports. The Pennsylvania inland waterways received a grade of D+. This rating is due to a lack of maintenance over the years which have led to delays, and poses a threat to industries that rely on waterways to transport its products and commodities. There is an apparent lack of use of the waterways due to these conditions. Figure 15 shows the decline of traffic on the waterways over an interval of 16 years. Not only does this decline mean that the waterways are not being fully utilized to their capacitance, it also means that there is a decline in revenue being created. Pittsburgh is

known for its three rivers (the Monongahela River, Ohio River, the Allegheny River), because of this passage it "has been named the start of the Federal Marine Highway," known as M-70. This highway is a major waterway connects Pittsburgh all the way down to Kansas City, and is a major source of profit (Figure 16). As we see the traffic decrease in the waterways of Pittsburgh, an impact on M-70 will follow as well. The budget seems to play a major role in the amount of traffic a waterway receives when examining the inland waterway of Pittsburgh (Figure 17). In order to understand the amount of traffic, one can consider the number of lock closures as the amount of traffic coming and leaving from a certain portion of the waterway.

3.4 Pennsylvania Freight Rail System. Unlike most of the transportation methods in Pennsylvania, freight rail has good ratings. With a rating of a B, freight rail system is in good condition, and in the 80 to 89 percent range. Pennsylvania has one of the largest freight rail systems in the U.S.; it is ranked number four in the nation. Rail has been described as the "safest and most cost efficient mode of transporting hazardous materials, coal, industrial raw materials, and large quantities of goods. “Being one of the leading state in freight railroads, Pennsylvania has 65 freight railroads that expand approximately 5,145 route miles (Figure 18). A mass majority of these lines move through the state, and do not start or end in Pennsylvania. The upkeep of such a large system would seem to be very difficult, but many railways are managed by the private owners (majority of these are larger railroads). "Short line railroads" on the other hand are not so fortunate. There is a lack of funding for these lines because they are not as profitable, and therefore it is less likely that a company will want to fund these railroads. Lines that are not frequently traveled are often considered abandoned, and are considered a risk. There are about 124 rail lines that fall under this category, and 96 of these of their lack of traffic. These 96 carry less than one million gross tons annually, making them extremely low in density traffic. Some of these lines, which have potential to grow and become profitable, are part of the publicly-funded tail preservation efforts where they will receive benefits to help them stay open. With a projected increase of 1.2 to 1.8 percent of freight on these rails annually, it is crucial that there is funding to keep railroads in good condition. However, less funding overall is being provided (Figure 19) and this can be detrimental. As the demand for rail transportation increases, the funding to keep these railroads must also increase. In doing so, there must be funding for bridges as well, so this can be extremely costly (bridges need about one million dollars per bridge for repair, and this is a minimum).

SECTION 4 STANDARD CAPACITY FOR ALTERNATE TRANSPORTATION MODES

4.1 Cargo Capacity. With respect to cargo capacity, barges, 15 barge tows, and 100-car trains are around the same tier of carrying capacity. Semi-trucks are not a viable option for large loads because a single truck can only hold 26 tons. In comparison, barges can carry 1500 tons, 100-car locomotives can carry 10,500 tons, and 15 barge tows can carry 22,500 tons. This is shown in Figure 12.

4.2 Equivalent Units. Out of these three alternative transportation modes, the 15-barge tow is easily the largest. A single 15-barge tow is equal to 2.25 100-car locomotives and 870 semi-trucks. This is shown in Figure 12.

4.3 Equivalent Lengths. With respect to the units provided in the 4.2 evaluation, 870 semi-trucks would have a longer span than the other categories of transportation. The length of 870 semi-trucks (11.5 miles) is about 4.2 times longer than the 100-car locomotive (2.75 miles), and about 46 times longer than the length of the 15 barge tows (.25 miles). This is shown in Figure 12.

SECTION 5 TRANSPORTATION COSTS AND CONCEPT OF OPERATIONS (ConOps)

5.1 Trucks. The American Transportation Research Institute has been analyzing the cost of operation trucks since 2008. They have not yet released the analysis for 2015, but for 2014 they were able to produce the results as follows. The typical transportation cost for a truck consist of two main components, vehicle-based and driver-based cost. Throughout the U.S. the cost of operating an upkeep for a truck vary depending on the region. They found that in 2013 the average marginal cost per mile in the Southeast was the cheapest, and was only about $1.615. The region with the highest cost was the Northeast, and the cost in this region came to about $1.756 per mile (average marginal cost.). A vast majority of this cost consists of the price of fuel, and the fluctuations over the years help account for majority of the change in the cost of operations of such vehicles. The average marginal cost per hour in 2013 came to about $67.00 per hour. It seems as though the cost of trucking will continue to stabilize, and the amount per hour will only fluctuate between two and five dollars in upcoming years. Most of this fluctuation will be due to the cost of gas, because it makes up most of the cost in general, and it is not always at a set price. Further explanation in cost can be found in Figure 21 to 23.

5.2 Barges. According to the Arkansas Waterways Commission, fuel efficiency is the biggest advantage when it comes to barges. Barges being more fuel efficient that both rail and truck explains why the average cost is cheaper in certain aspects. They created a cost analysis and found that it would cost only 97¢ to ship a ton mile, while rail would cost $2.53, and trucks would be the most expensive with the cost of $5.35 per ton mile. They came to the conclusion that a barge would travel much further on a gallon of fuel when compared to the other two types of transportation. A truck only travels about 155 ton miles, while by rail a train would travel 413 ton miles, and a barge travels an average of 576 ton miles per gallon of fuel. They failed to take into account the cost of labor and the amount of time that it takes to get from point A to B. Since barges do operate on waterways they must factor in the amount of time and money that is lost when stuck at locks and if there are any factors to slow down the process. Pictures can be found in Figure 24.

5.3 Railroad. There are many components that come into play when we talk about the cost of operating a train. The components are not as simple as the ones of the other two transportation methods. We must analyze the upkeep of the train and the upkeep of the railroad. Steer Davies Gleave did some research and estimated how costly it would be to manage a train. Trains cost is dependent on the crew and staff of operation. It is also dependent on the number of cars that are running, and this all has to be factored into the equation (Figure 26-27). Metrolink was able to devise the amount that it would cost them annually to about $121,229,000 averaging about $46.15 per mile. With maintenance and admin factored in they totaled to about $66.59 per mile.

5.4 Most Economical Transportation Solution. After looking at the total costs to ship by using the various modes of transport, and after incorporating fuel costs, we concluded that shipping by fifteen barge tows are the most efficient. Using inland waterways, we can ship vast amounts of freight, for a lowered cost, while also becoming more environmentally friendly.

5.5 Concept of Operations (ConOps).

a. General Description. We decided that we are going to create a hybrid system that focuses primarily on using barges to ship freight, but will also incorporate the use of locomotives. By using seven, fifteen barge tows, we will be able to ship the main bulk of our 165,000 tons of freight using inland waterways. However, this doesn't reach the needed amount of freight, so we plan to supplement the remaining freight by transporting it via one Tier III locomotive pulling seventy-five cars. Using the train will also help to keep a constant flow of freight because transporting by sea's only weakness is that it is slow.

b. Operational Policies and Constraints. Because of the slow shipping times, we are going to have to run all barges constantly. To avoid congestion on the waterways, we will stagger the fifteen barge tows so there is a steady amount of freight coming into Pittsburgh. Our main operational constraint is that we need water deep enough to be able to ship. If there is a drought, we could run into increased traffic on main shipping channels.

c. Performance characteristics. Our system has the largest shipping capacity available due to the use of barges. Barges also are very environmentally friendly by releasing few pollutants into the air. This is also the safest mode of transportation with next to no deaths per year. The only drawback to our system is that barges are very slow, but we hope to circumvent this problem by staggering ships to create a constant flow, and then using our locomotive to bring in smaller shipments at a faster rate.

d. Operational Impacts. Barges are very large, but inconvenience people very rarely because they are on rivers and surprisingly don't create enormous waves. In addition, they are very eco-friendly and will be a huge improvement over the locomotives being used now.

e. Continuity of Operations. Operations are likely to continue after the event of a freak accident purely because they are so unlikely to happen. Barges are enormous vessels which can navigate rough waters with ease, and in addition to that, individual barges will never be alone.

SECTION 6 EPA DIESEL EMISSION STANDARDS

6.1 Background. The Environmental Protection Agency (EPA) is an organization with in the United States and is headquartered in Washington, DC. The EPA's main goal is to try and protect human and environmental health. In relation to locomotives the EPA is helping to implement programs to reduce the emissions from diesel locomotives. The standards given to locomotive tiers are based on the high-efficiency catalytic aftertreatment technology from newly manufactured engines built in certain years. Older locomotive can receive standards as well only when they are remanufactured though.[6]

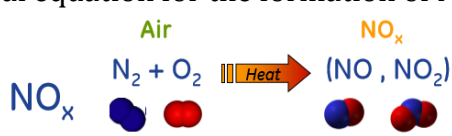
6.2 Tier 0-2 Standards. The emission standards are given based on the years in which the locomotive or the locomotive engine were manufactured/ remanufactured. Tier 0 standards apply to locomotives produced between the years 1973 to 2001. Tier I standards apply to locomotives produced between the years 2002 to 2004. Finally Tier II standards apply to locomotives produced between the years 2005 to 2011. The corresponding emission standards for Tiers 0 – 2 locomotives are down below in Table One.

6.3 Tier 3-4 Standards. The emission standards for Tier 3 – 4 locomotives are similar to the standards for Tier 0 – 2. Tier III locomotives standards are for locomotives built/ remanufactured between 2012 and 2014. These standards are met using engine technology. Tier IV locomotive standards are the same as Tier III, recently built of remanufactured locomotives. The difference between the two Tiers is that Tier III is only for near-term standards and Tier IV is for long-term standards. Since Tier IV is for long-term standards Tier IV locomotives have emission control devices such as particulate filters and NOx emissions control. The corresponding emission standards for Tiers 3 – 4 locomotives are down below in Table Two.

SECTION 7 DIESEL ENGINE EXHAUST EMISSIONS (DEEE)

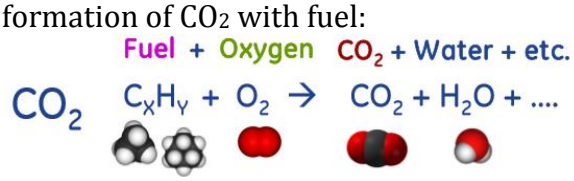
7.1 Diesel Emission Chemistry. In this section we will be explaining general chemical emissions into public air. There are four basic emissions into air they are NOx, Particulate Matter (PM), CO_2, and Hydrocarbons. Descriptions of each emissions type will be described below.

a. NOx. NOx is a formation of NO, nitric oxide, and NO_2, nitrogen dioxide. NOx is formed when air, oxygen and nitrogen, is heated. The higher the temperature the more NOx formed also when the air spends more time getting heated up at a certain temperature causes more formation of NOx. Common places NOx can be formed includes, areas of high motor vehicle traffic, air pollution and can also be produced naturally by lightening. The chemical equation for the formation of NOx:



b. Particulate Matter (PM). Particulate Matter is the sum of all solid and liquid particles suspended in air, many of which are hazardous. It contains smoke, pollen, dust, soot, etc. In context of our project Particulate Matter refers to a cylinder in which combustion occurs, the combustion process forms soot. A diagram showing this process is located below as Figure 25.

c. CO_2. Carbon Monoxide, CO_2, is a colorless, odorless, and tasteless gas that is slightly less dense then air. CO_2 is formed in direct proportional to any amount of fuel consumed. When humans reduce fuel consumption CO_2 is reduced and visa-versa, increase fuel consumption CO_2 is increased. CO_2 is also produced through combustion. The equation below is essentially a combustion reaction of fuel. The basic chemical equation for the formation of CO_2 with fuel:



d. Hydrocarbons (HC). Hydrocarbons are the simplest organic compounds. Hydrocarbons like its name suggest only contain chains of hydrogen and carbon molecules. Hydrocarbons form emissions like CO_2 above hydrocarbons when combusted, added to O_2, form CO_2 and H_2O. Again like CO_2 formation common places for the formation of hydrocarbon emissions trace back to ignition of one's car.

7.2 Diesel Emission Reduction Strategies. A popular strategy to help reduce diesel emissions is a process called retrofitting. Retrofitting technologies have proven to be cost-

effective and the vehicle is still able to perform as usual. Retrofitting involves the addition of an emission control device to the engine exhaust. Retrofitting can eliminate up to 90%of pollutants in certain cases. Some types of emission control devices include diesel oxidation catalysts, diesel particle filters, NOx catalysts and exhaust gas recirculation.[5] There are two other strategies that can help reduce emissions, the two are replace and refuel.[5] Replace involves replacing the old engine with a new engine, this strategy is most effective if the diesel powered equipment will have a longer life than that of the engine. Finally refuel is switching over to and alternative fuel. Some examples of alternative fuels include emulsified fuels, biodiesel, natural gas, propane or ethanol.[5]

7.3 Alternate Fuels. As briefly discussed above a way to reduce diesel emissions is through refuel. Refueling is switching the diesel currently used in equipment over to emission reducing fuels. Some examples of alternative fuels include emulsified fuel, biodiesel, natural gas, propane or ethanol. The two popular alternative fuels are emulsified fuels and biodiesel. Emulsified fuels is a blended mixture of diesel fuel, water, and other additives. This alternative fuel reduces both PM and NOx emission. The water is suspended in droplets within the fuel, this creates a cooling effect in the combustion chamber that decreases the NOx emissions.[5] Emulsified diesel can be used in any type of engine. Switching over to emulsified fuels one will see a reduction on NOx by about 10-20 percent and PM by about 50-60 percent.[5]

The other more known alternative fuel is biodiesel. Biodiesel is a domestically produced, renewable fuel that can be manufactured from new and used vegetable oils and animal fats.[5] This alternative fuel is produced by reacting vegetable or animal fats with methanol or ethanol to produce a fuel similar to diesel, this mixture is then mixed with petroleum diesel so that it can be used in a diesel engine.[5] Using biodiesel can decrease carbon monoxide (CO) by 10%, a decrease in PM by 15%, and a 20% decrease in sulfate emissions. One con to this alternative fuel is that in some cases it has actually proven to increase NOx emissions by about three percent on some types of heavy-duty engines.[5]

7.4 Human Health Issues. These different types of emissions as described cause different human health issues. For example the production and emission of NOx in the form of ground-level ozone can cause lung tissue damage and can damage the lungs function for children who have asthma or people who work out outside (running).[2] Particles of NOx combined with moisture can cause changes in the ease of breathing and can affect the respiratory system, ultimately it can lead to premature death.[2] NOx emissions also affect large bodies of water. NOx emissions is actually the largest pollutant of the Chesapeake Bay.[2] High concentrations of CO_2 in the air when inhaled can produce a state of hypercapnia, excessive amount of CO_2 in the blood. The concentration of CO_2 today is not at a level that can cause a problem like so but it is not long before we reach it.[3] PM have the same effects on human health. PM can cause aggravated asthma, irregular heartbeat, nonfatal heart attacks, etc..[4]

SECTION 8 LOCOMOTIVE FLEET UPGRADE

8.1 Alternatives. Options for Alternative Upgrades:

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

The options given are to sell the locomotives and purchase new ones, upgrade the current fleet with possible after-treatment, or to utilize alternative fuels to lower emissions. All have advantages and disadvantages over each other with respect to cost-efficiency and plausibility. For example, the easiest option would be to sell the fleet and purchase new trains, however, this is the least cost-efficient upgrade.

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. In the GE presentation we were given investment data. This investment data given included the price to upgrade a diesel locomotive, the price for a new locomotive, and the prices for alternative fuels. The values given to use are written below.

Diesel Locomotive Upgrade		New Locomotive		Alternative Fuels	
Tier II → Tier III	$750 K	Tier III Locomotive	$3 M	Locomotive Upgrade	$1 M
After Treatment	$100 K	Tier IV Locomotive	$4 M	Fueling Station	$1 B

8.4 Upgrade Strategy. The chosen use of barges negates the complete overhaul of the fleet as most of the fleet will be sold to be replaced with barges. The single 75-car locomotive that remains will be fully upgraded to tier three and will be treated with the after-treatment which gives an advance well worth the cost. This strategy will reach EPA requirements and even return a profit.

8.5 Upgrade Schedule and Costs. As seen in table three, the cost of a new dry barge is $200,000 whereas the selling price of a tier II locomotive is around $1 mil. There are 105 barges in total being purchased and 49 trains being sold. Also, one train is being fully upgraded to Tier III and given the after-treatment for a total of $850,000. Therefore, the benefits greatly out-price the costs giving a remarkable profit of $27,250,000 using this upgrade strategy.

SECTION 9 SUMMARY

The upgrade strategy illustrated in this report shows the huge advantage that barges have over the other cargo transportation methods. They annihilate the competition in the categories of economic efficiency and environmental friendliness, and can carry a large amount of materials at one time. With the distance needed to travel given in this statement of work and the importance of protecting the environment from harmful emissions, barges fit the transportation needs better than the other two forms of transportation. It is also important, however, to have various forms of shipping methods in case one fails; thus, it is advantageous to upgrade at the very least one train for any random emergency that may occur. With the use of this strategy, the shipping industry progresses toward the future.

SECTION 10 REFERENCES

1. "Pennsylvania's Infrastructure Matters." *Report Card for Pennsylvania's Infrastructure*. American Society of Civil Engineers, 2014. Web. 07 Dec. 2015.

2. "Health and Environmental Impacts of NOx." - *Nitrogen Dioxide*. N.p., n.d. Web. 07 Dec. 2015.

3. "CO2 Science." *RSS*. Center for the Study of Carbon Dioxide and Global Change, n.d. Web. 07 Dec. 2015.

4. "Health." *Health*. United States Environmental Protection Agency, 10 Sept. 2015. Web. 07 Dec. 2015.

5. "Diesel Retrofit." *What Is Retrofit?* MECA, n.d. Web. 07 Dec. 2015.

6. "Locomotives." *Locomotives*. United States Environmental Protection Agency, 9 May 2014. Web. 07 Dec. 2015.

7. Murry, Dan, and W. Ford Torrey, IV. "An Analysis of the Operational Costs of Trucking: 2014 Update." *An Analysis of the Operational Costs of Trucking (2014)*. ATRI Online. American Transportation Research Institute, Sept. 2014. Web. 7 Dec. 2015.

8."Why Waterways?" *Arkansas Waterways Commission*. AWC, n.d. Web. 07 Dec. 2015

Figure 1. Typical Diesel Truck and Trailer.

Figure 2. Typical Diesel-Electric locomotive.

Figure 3. Typical Railroad Hopper

Figure 4. Typical Railroad Refrigerator Car

Figure 5. Typical Railroad Box Car

Figure 6. Typical Railroad Intermodal Car

Figure 7. Typical Railroad Tank Car

Figure 8. Typical Railroad Flat Car

Figure 9. Typical Inland Water Ways Barge and Tug.

Figure 10. Typical Barge Lock

Figure 11. Inland Waterway System

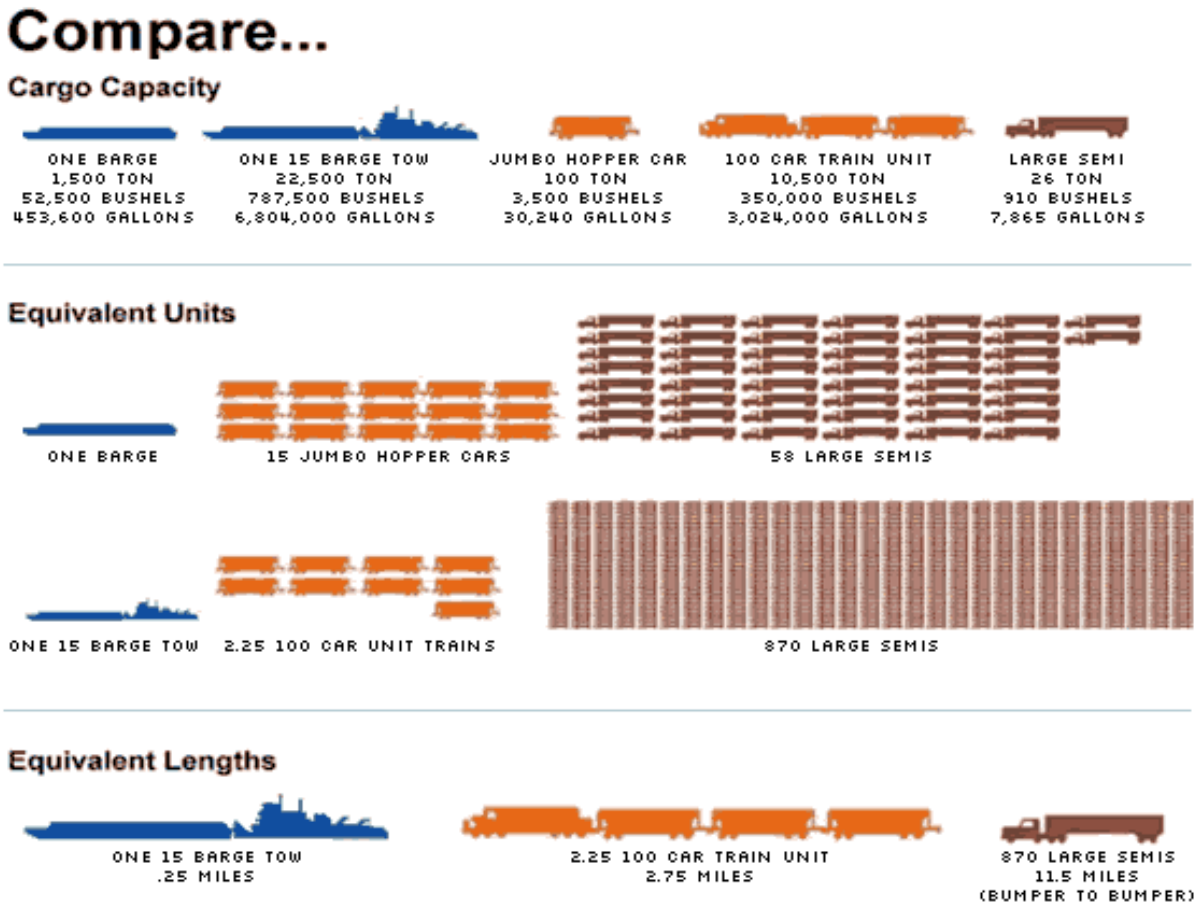


Figure 12. Alternative Transportation Comparison

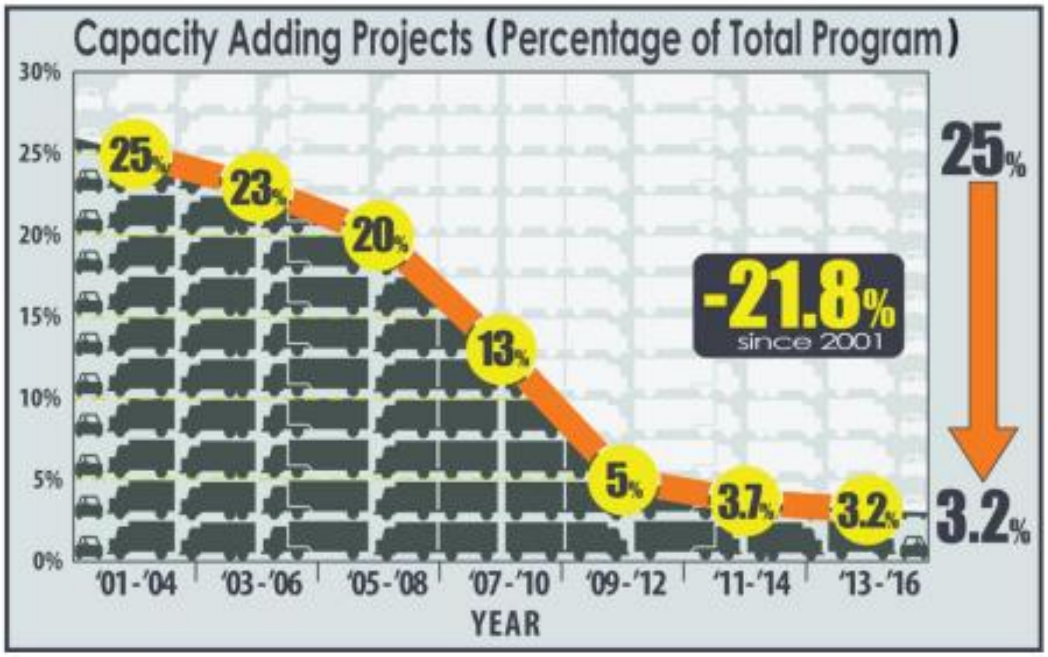


Figure 13. Pennsylvania Road Capacity

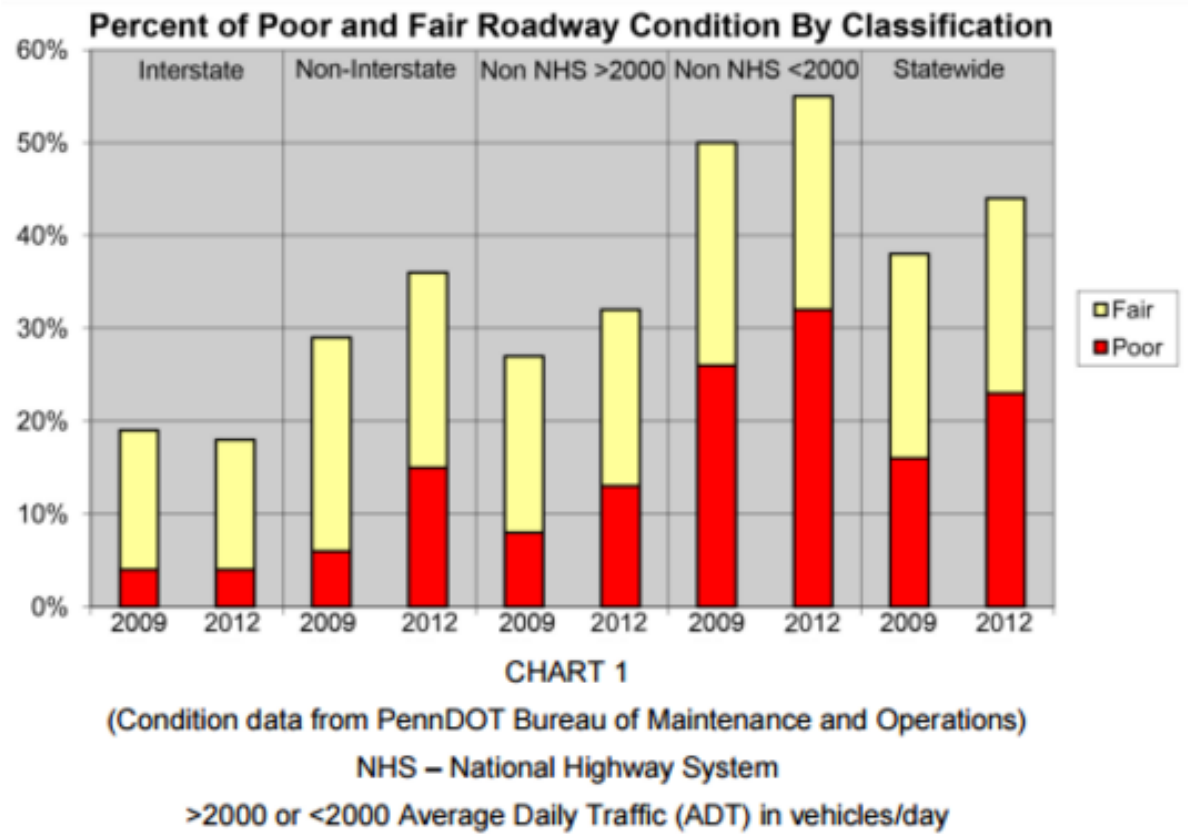


Figure 14. Pennsylvania Road Conditions

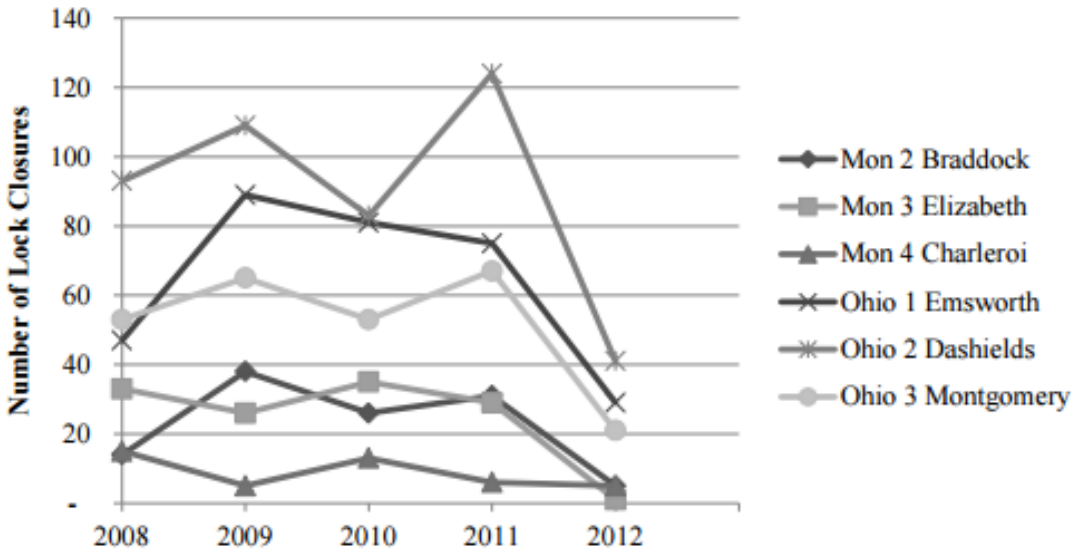


Figure 15. Pittsburgh Inland Traffic Estimate by Lock Closures

Figure 16. Marine Highway Breakdown

Table 3. USACE Pittsburgh District Budgets (10) (11)

Corps of Engineers Work Plan Budgets ($ millions)					
	2010	2011	2012	2013	2014 (proposed)
Investigations					
Upper Ohio Navigation Study, PA	1.255	1.347	1.588	0.998	
Construction					
Emsworth Locks and Dam, Ohio River	25.0	9.806	0	6.285	
Locks and Dams 2, 3 and 4, Monongahela River	6.21	8.1	1.2	22.2	1.96
Southeastern Pennsylvania			2.3		
O&M					
Allegheny River	9.039	8.874	4.367	4.308	4.892
Monongahela River	16.758	16.1	16.648	13.658	11.035
Ohio River Locks and Dams, PA, OH & WV	21.470	31.320	29.862	21.221	30.905
Ohio River Open Channel Work, PA, OH & WV	0.516	0.625	0.607	0.681	0.359

Figure 17. Pittsburgh Budget for Waterways

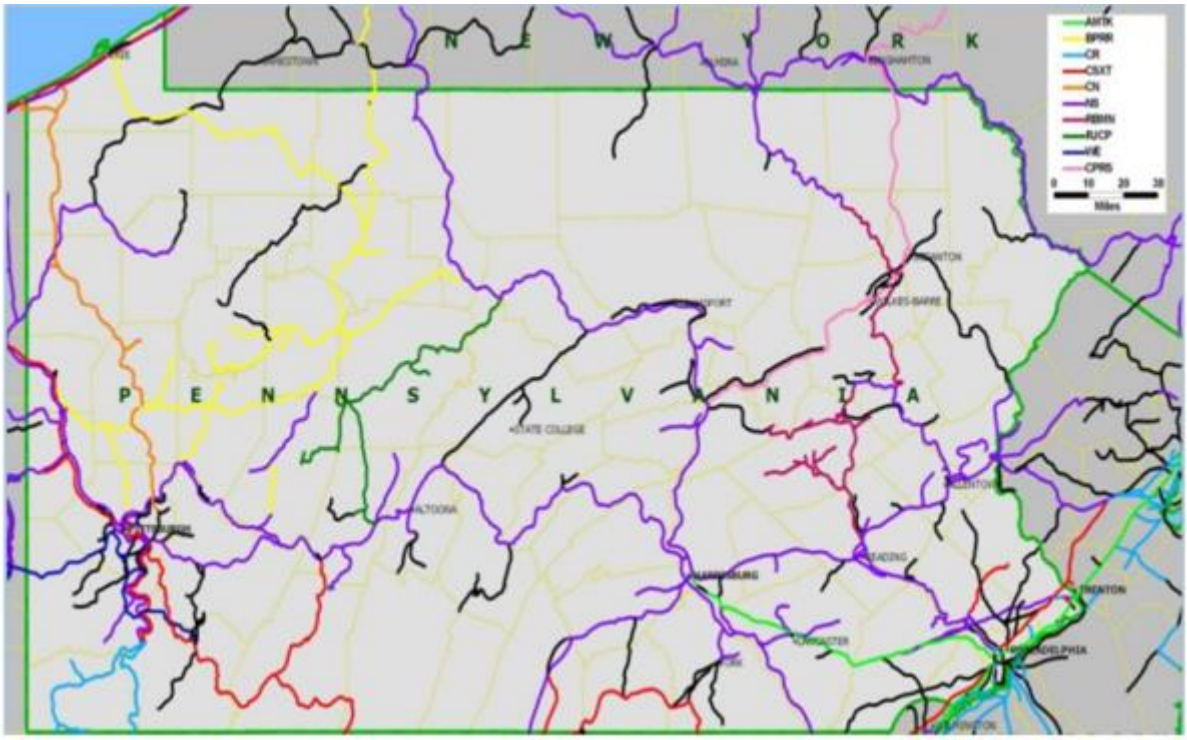


Figure 18. Freight Rail Line in Pennsylvania

Rail Freight Assistance Benefits 2008-2014

Fiscal Year	Grant Type	State Investment	Total Project Cost	Number of Projects Funded	Jobs Created	Trucks Removed
2012	RFAP	$6,122,099.00	$8,745,855.00	18	440	124796
2012	CB	$44,430,080.00	$63,471,542.00	21	2165	854136
2012	Act 13	$523,000.00	$747,143.00	1	0	6251
Total		**$51,075,179.00**	**$72,964,540.00**	**40**	**2605**	**985183**
2013	RFAP	$5,871,022.00	$8,440,895.00	15	848	64272
2013	CB	$27,442,141.00	$39,203,059.00	14	3615	138232
2013	Act 13	$1,307,000.00	$1,867,143.00	4	197	18604
Total		**$34,620,163.00**	**$49,511,097.00**	**33**	**4660**	**221108**

Figure 19. Funding for Pennsylvania Railways

Equipment Type	Number of Trucks/ Trailers	Average Age (Years)	Average Miles Driven per Year per Truck
Straight Trucks	557	7.6	32,901
Truck-Tractors	29,523	3.9	118,800
Other Trucks	3	7.0	65,000
Total Trucks	**30,083**		
28' Trailers	28,779	7.9	
45' Trailers	1,478	12.3	
48' Trailers	14,683	9.5	
53' Trailers	33,723	6.5	
Other Trailers	6,121	7.6	

Figure 20. Participants in ATRI Survey

Figure 1: Average U.S. On-Highway Diesel Prices, 2008 – 2013[14]

Figure 21. Diesel Prices Fluctuation

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 22. Average Marginal Costs per Hour for Trucks

Motor Carrier Cost Centers	Midwest	Northeast	Southeast	Southwest	West
Vehicle-based					
Fuel Costs	$0.639	$0.691	$0.634	$0.682	$0.608
Truck/Trailer Lease or Purchase Payments	$0.138	$0.165	$0.145	$0.129	$0.190
Repair & Maintenance	$0.137	$0.154	$0.159	$0.182	$0.183
Truck Insurance Premiums	$0.065	$0.062	$0.053	$0.071	$0.081
Permits and Licenses	$0.044	$0.037	$0.026	$0.042	$0.034
Tires	$0.031	$0.024	$0.020	$0.029	$0.034
Tolls	$0.022	$0.039	$0.014	$0.028	$0.011
Driver-based					
Driver Wages	$0.437	$0.453	$0.443	$0.402	$0.423
Driver Benefits	$0.135	$0.131	$0.121	$0.112	$0.122
TOTAL	**$1.647**	**$1.756**	**$1.615**	**$1.677**	**$1.687**

Figure 23. Average Marginal Cost per Mile by Region (Trucks)

Figure 24. Fuel Efficiency and Cost Comparison

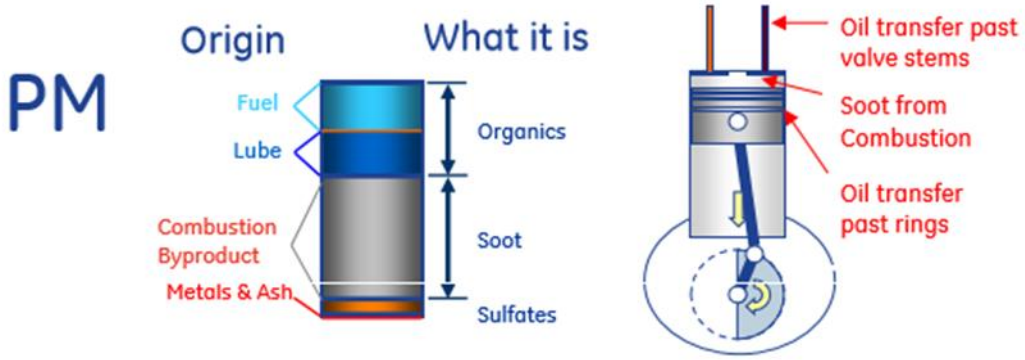


Figure 25. Particulate Matter (PM) Production

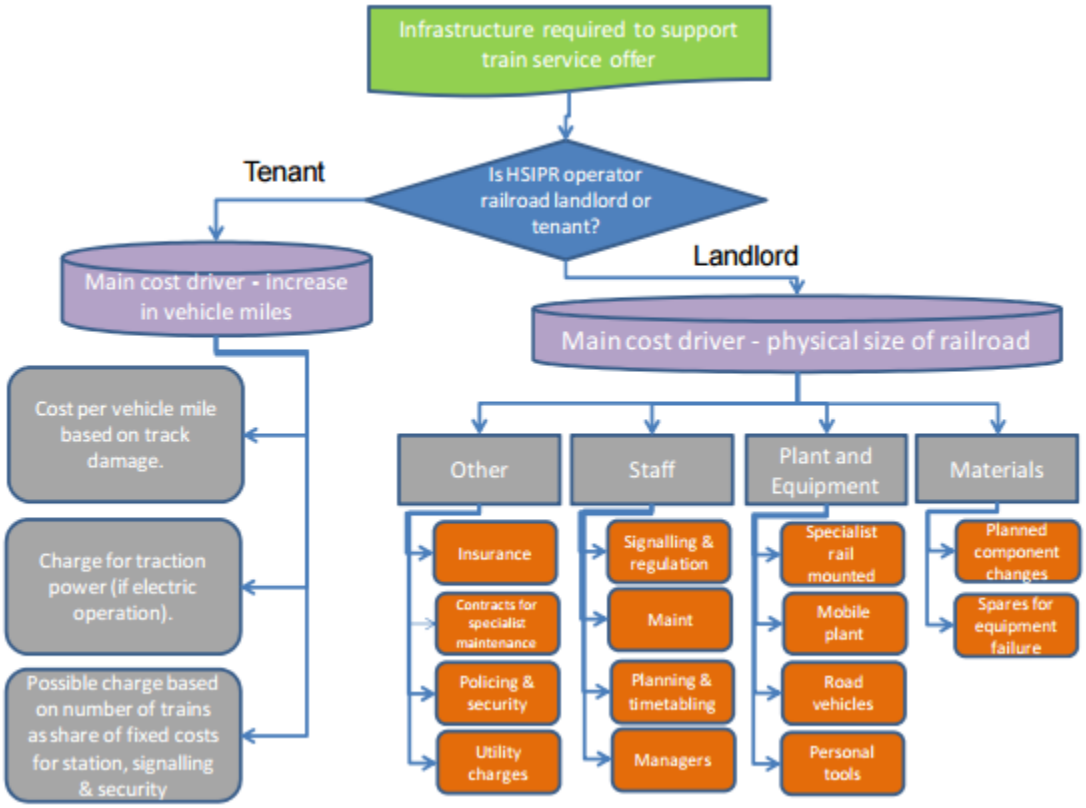


Figure 26. Factors

Cost component	Units	Unit cost	Total cost ($m)	
Sales & admin	Passengers	$5.00	$52.775m	19%
Shunting	Train	$87.80	$3.429m	1%
Train servicing	Train-hour	$92.20	$11.112m	4%
Driving	Train-hour	$81.80	$9.760m	3%
Operations	Train-mile	$0.03	$1.315	1%
Energy	Train-mile	$1.50 ($0.10 per KHhr)	$69.135	25%
Infrastructure maintenance	Train-mile	$3.00	$132.691	47%
			$280.217m	**100%**

Figure 27. Costs from SDG

Table 1: Tier 0-2 Emissions Standards				
	HC	CO	NOx	PM
Tier 0 (1973 – 2001)				
Line-Haul	1.0	5.0	9.5	0.60
Switch	2.1	8.0	14.0	0.72
Tier 1 (2002 – 2004)				
Line- Haul	0.55	2.2	5.5	0.20
Switch	1.2	2.5	8.1	0.24
Tier 2 (2005 - 2011)				
Line-Haul	0.3	1.5	13.5	0.34
Switch	0.6	2.4	19.8	0.41

Table 1. Tier 0 -2 Emission Standards

Table 2: Tier 3-4 Emissions Standards				
	HC	**CO**	**NOx**	**PM**
Tier 3 (2012 – 2014)				
Line-Haul	0.30	1.5	5.5	0.10
Switch	0.60	2.4	5.0	0.10
Tier 4 (2015 – Now)				
Line-Haul	0.14	1.5	1.3	0.03
Switch	0.14	2.4	1.3	0.03

Table 2. Tier 3 – 4 Emission Standards

Upgrade Finances

Costs:	Quantity:	Price/Unit	
Barge	105	-$200,000	-$21000000
Train Tier III Upgrade	1	-$750,000	-$750000
After Treatment	1	-$100,000	-$100000
Benefits:			
Tier II Train	49	$1,000,000	$49000000
			0
			0
		Net Total:	$27150000

Table 3. Upgrade Costs/Profits