



**PennState**  
College of Engineering

**ENGINEERING DESIGN, TECHNOLOGY,  
AND PROFESSIONAL PROGRAMS**

**The Pennsylvania State University  
University Park Campus**

# **Freight, Fuel, & Emissions**

**GE Transportation**

**EDSGN 100**

**Section 002**

**Design Team #8  
Team Steve  
Fall 2015**



Logan Smith  
Scott Foley  
Yasin Alawadhi  
Abdulla Alawadhi

Submitted to:  
Professor Berezniak

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

08 Dec 2015

# ACKNOWLEDGMENTS

## Penn State University

- **Dean, College of Engineering**  
Amr Salah Elnashi, Dean of Engineering
- **Department Head, SEDTAPP**  
Sven Bilen, Head, School of Engineering Design, Technology
- **Course Instructor**  
Professor Berezniak
- **Laboratory Assistants**  
Keri Ford, Engineering

## GE Transportation

- **Jamie Miller, Senior Vice President of GE and President and Chief Executive Officer, GE Transportation**
  - **James Bunce, GE Transportation, Senior Manager – LNG Program**  
Global Headquarters  
500 W Monroe St  
Chicago, IL 60661 USA
-



# TABLE OF CONTENTS

## **SECTION 1. EXECUTIVE SUMMARY**

## **SECTION 2. INTRODUCTION**

- 2.1 PROJECT OBJECTIVES
- 2.2 PROJECT BACKGROUND
- 2.3 PROJECT SPONSOR BACKGROUND
- 2.4 PROJECT DESCRIPTION
- 2.5 PROJECT FREIGHT REQUIREMENTS
- 2.6 TRANSPORTATION MODE COMPARISONS

## **SECTION 3. TRANSPORTATION INFRASTRUCTURE CONDITION AND CAPACITY**

- 3.1 INTRODUCTION
- 3.2 PENNSYLVANIA ROADS AND BRIDGES
- 3.3 PENNSYLVANIA INLAND WATER WAY SYSTEM
- 3.4 PENNSYLVANIA RAIL SYSTEM

## **SECTION 4. STANDARD CAPACITY FOR ALTERNATE TRANSPORTATION MODES**

- 4.1 CARGO CAPACITY
- 4.2 EQUIVALENT UNITS
- 4.3 EQUIVALENT LENGTHS

## **SECTION 5. TRANSPORTATION COSTS AND CONCEPT OF OPERATIONS (ConOps)**

- 5.1 TRUCKS
- 5.2 BARGES
- 5.3 RAILROAD
- 5.4 MOST ECONOMICAL TRANSPORTATION SOLUTION
- 5.5 CONCEPT OF OPERATIONS (CONOPS)

## **SECTION 6. EPA DIESEL EMISSION STANDARDS**

- 6.1 BACKGROUND
  - 6.2 TIER 0-2 STANDARDS
  - 6.3 TIER 3-4 STANDARDS
-



## **SECTION 7. DIESEL ENGINE EXHAUST EMISSIONS (DEEE)**

- 7.1 DIESEL EMISSION CHEMISTRY
- 7.2 DIESEL EMISSION REDUCTION STRATEGIES
- 7.3 ALTERNATE FUELS
- 7.4 HUMAN HEALTH ISSUES

## **SECTION 8. LOCOMOTIVE FLEET UPGRADE**

- 8.1 ALTERNATIVES
- 8.2 EXISTING FLEET MAKE-UP
- 8.3 INVESTMENT DATA
- 8.4 UPGRADE STRATEGY
- 8.5 UPGRADE SCHEDULE AND COSTS

## **SECTION 9. SUMMARY**

## **SECTION 10. REFERENCES**

---



## **SECTION 1   EXECUTIVE SUMMARY**

This group has been tasked with coming up with the best possible solution for the issue of aging trains for the shipment of goods in and out of Pittsburgh. The issue is brought about by the aging fleet of diesel powered trains that currently bring goods in and out of the city. These trains needed to be upgraded or replaced by either newer trains or other forms of transportation. These other forms of transportation include both trucks and barges. This group chose the latter for the solution to this problem. The outright cost is much less than that of both upgrading the trains or using trucks, with an added bonus of being a safer, less volatile form of getting goods from one place to another. Barges are the best option for the aging train problem in Pittsburgh.



## **SECTION 2 INTRODUCTION**

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

**2.2 Project Background.** Every day into and out of the port city of Pittsburgh, approximately 165,000 tons of freight or minerals (coal, etc.) per day travel via rail. Smog from the locomotive emissions is a key complaint of the city residents. Smog is generated from engine-emitted NOx. Tier 2 locomotives used to haul freight are approaching age for overhaul, at which time investments will be required to meet EPA Tier 3 (or higher) requirements. Suggestions have been made to address locomotive emissions (i.e. smog) by 1) Upgrade the locomotive fleet to meet more recent emissions guidelines set by the EPA. A few options may exist to meet the new guidelines: Sell existing fleet and purchase new locomotives. Upgrade fleet with exhaust after-treatment hardware. Utilize alternate fuels (Biodiesel, CNG, LNG, etc.) which may produce less NOx. 2) Alternate freight shipping methods:

- By Sea
- By Air
- By Ground i.e., trucking

**2.3 Project Sponsor Background.** GE Transportation, a unit of GE (NYSE: GE), solves the world's toughest transportation challenges. GE Transportation builds equipment that moves the rail, mining, and marine industries. GE's fuel-efficient and lower-emissions freight and passenger locomotives; diesel engines for rail; marine and stationary power applications; signaling and software solutions; drive systems for mining trucks; and value-added services help customers grow. GE Transportation is headquartered in Chicago, IL, and employs approximately 13,000 employees worldwide.

**2.4 Project Description.** Each design team should research and evaluate the suggestions made for fleet upgrade or alternate shipping methods. For upgrades, consider physical constraints of new hardware, as well as fuel storage requirements. Provide your recommendations, commenting on impact to:

- 1) Emissions/Regulatory requirements
- 2) Costs, fuel, infrastructure, etc.
- 3) Freight throughput/capacity
- 4) Public opinion
- 5) On time delivery



**2.5 Project Freight Requirements.** There are 20 trains that enter and exit Pittsburgh each day. These twenty trains consist of five mineral trains and fifteen freight trains. Each mineral train is 12,000 ton with three locomotives and each freight train is 7,000 ton with two locomotives.

## **2.6 Transportation Mode Comparisons.**

**a. Trucks.** Large semi-trucks are known to typically carry perishable products and non-perishable products. These products include light manufacturing goods such as food, clothing, and retail goods. Large semi-trucks are typically between 40 and 53 feet long and can carry up to 20 tons of product within one trailer. Transportation of goods using trucks is very beneficial because trucks provide door-to-door service while trains and barges typically cannot deliver to factories or stores directly. Truck transportation also travels at the fastest average speed, however; their speed of travel is greatly restricted during poor weather and/or traffic. (See Figure 1: Standard Large Diesel Truck with Trailer)

**b. Barges.** Inland waterway barges transport nonperishable products such as liquids, minerals, petroleum, and lumber because their transportation speed is rather slow and perishables could expire during transit. The waterways are a form of public transport, meaning the purchasing of licenses to use the waterway is unnecessary because they are open to the public. The great lakes along with their lock and dam system have the least amount of traffic compared to transportation using trucks or trains. Each barge measures 35 feet by 195 feet and can carry up to 1500 tons of cargo. Barges have the highest capacity of all the proposed shipping alternatives, however; barges are just as weather dependent as trucks because during poor weather, (drought, flood, ice), transportation will be slowed greatly, if not halted until there are better weather conditions. Barges are also restricted to waterways and therefore cannot perform a door-to-door service like semi-trucks. (See Figure 7: Inland Water Barge with Tug)

**c. Railroad.** Transportation by railroad is the most reliable form of proposed transportation methods. Trains tend to carry both perishable and nonperishable products such as minerals, chemicals and agricultural products (corn and other vegetables). The average train car can carry 80 to 100 tons of material and there are around 60 to 80 cars per train with 2 to five locomotives pulling the cars. Trains are the most reliable form of transportation because they will continue to run even in poor weather. However, much like barges, trains are restricted to their tracks and a large portion of the shipping process for trains is spent waiting to load/unload. Train transportation also requires certain licenses in order to obtain the right-of-way for the railways. (See Figures 2-6 Depicting Locomotives and several different train cars)

## **SECTION 3    TRANSPORTATION INFRASTRUCTURE CONDITION AND CAPACITY**

**3.1 Introduction.** The 2014 Report Card for Pennsylvania Infrastructure is a form of reporting the condition of Pennsylvania's infrastructure as a whole, such as the condition of its bridges, waterways, and railways. The 2014 Report Card expresses how well Pennsylvania is caring for its infrastructure and what it can do to improve where it is failing.

**3.2 Pennsylvania Roads and Bridges.** In Pennsylvania, many of the roads and bridges are structurally deficient. Both the bridges and the roads score a D- as far as quality goes. Many of the bridges are in a state of failure. The original design has outlived its lifespan. Since the bridges are in such a state, they need to be repaired, which can cause major delays in ground transportation. Those bridges not being repaired will have additional weight limits that will allow for less and less loads with age until they are repaired or upgraded. The road conditions can attribute to more dangerous driving conditions. (See Figures 9: Pennsylvania Bridges in Disrepair and Figure 10: Typical Pennsylvania Roads)

**3.3 Pennsylvania Inland Water Ways.** The Pennsylvania inland Water Ways have a higher rating of D+ for their structural integrity and infrastructure. None of the 17 navigational Dams made the satisfactory rating, with less than half rating as fair. With more traffic, the delays increase dramatically for the lock system. Lock closures also cause major interruption in the delivery of goods. The lock and dam systems for western Pennsylvania have been in a state of major repair for the last decade and is now coming to a close, which could allow for barges being a more optimal option due to the increased traffic capacity. (See Figure 8: Inland Waterway System with Lock and Dam)

**3.4 Pennsylvania Freight Rail System.** The condition of the railway systems is far better than the waterways, roads and bridges. The railways rank at B putting this as the most reliable form of transportation of the three options. Much of the railways in this region have been updated to a point where they are compatible with many modern diesel engines in terms of width, strength and tunnel sizes. Pennsylvania has the fifth largest railway system in the country, therefore its maintenance costs would be large, however, the work would be spread over a large area, which leads to fewer delays. (See Figure 11: Pennsylvania Railroads)





## **SECTION 4    STANDARD CAPACITY FOR ALTERNATE TRANSPORTATION MODES**

### **4.1 Cargo Capacity.**

One Barge:	1500 Ton; 52,500 Bushels; 453,600 Gallons
One 15 Barge Tow:	22,500 Ton; 787,500 Bushels; 6,804,00 Gallons
Jumbo Hopper Car:	100 Ton; 3,500 Bushels; 30,240 Gallons
100 Car Train Unit:	10,500 Ton; 350,000 Bushels; 3,024,00 Gallons
Large Semi:	26 Ton; 910 Bushels; 7,865 Gallons

(See Figure 12, Capacity Section)

### **4.2 Equivalent Units.**

The capacity of one barge is equal to 15 jumbo hopper cars along with 58 large semi-trucks. The capacity of one 15 barge tow is equal to 2.25 100 car unit trains as well as 870 large semi-trucks. (See Figure 12, Units Section)

### **4.3 Equivalent Lengths.**

One 15 Barge Tow =	.25 Miles
2.25 100 Car Train Unit =	2.75 miles
870 Large Semis (bumper to bumper) =	11.5 miles

(See Figure 12, Equivalent Lengths Section)



## **SECTION 5**    **TRANSPORTATION COSTS AND CONCEPT OF OPERATIONS (ConOps)**

**5.1 Trucks.** The typical transportation costs for truck transport is \$1.29 per ton miles. This transportation cost means that the cost to transport approximately 165,000 tons of freight is around \$212,850 per mile. If using only semi-trucks, there would need to be approximately 6346 active semi-trucks to transport 165,000 tons.

**5.2 Barges.** The cost per ton miles varies greatly with the differing cargo loads. However, if we were to use 20,000 ton barges with a cost of \$0.0091 per ton miles, the cost per mile would be \$1,501.50. The minimum number of barges to transport 165,000 tons of freight is around nine, much less than the number of semi-trucks required.

**5.3 Railroad.** The cost per ton miles of trains is about \$0.0403, which leads to a cost per mile of \$6,649.50. The minimum number of 100 car unit trains needed to transport 165,000 tons of freight is 16. This is not quite as few as the number of barges needed and the cost per mile is still larger than that of barges.

**5.4 Most Economical Transportation Solution.** The most efficient and economical solution for the cargo shipment issue is barges as they offer the least cost and do not need to be upgraded. The costs of trucks is way too high to even consider that an option. Trains are also over four times as expensive as barges are and need to be upgraded or replaced in order to use them. Therefore barges are definitely the way to go.

### **5.5 Concept of Operations (ConOps).**

- a. General Description.** The use of barges appears to be the most reasonable and cost effective option for shipping materials such as minerals, coal, etc. In order to barges the main means of transport of the materials, the fleet of trains should be sold, using the money from the sale to purchase between 10-12 barges. Approximately nine barges will be needed to transport around 165,000 tons of freight into and out of Pittsburgh. These barges will use the great lakes and other inland waterways to transport freight. Since transporting on the great lakes is open to the public, there are no additional costs during transit, however; there are minor costs due to docking charges.
- b. Operational Policies and Constraints.** As with any form of transportation and shipping, there are certain constraints that must be adhered to. For one, the water levels for the channels needs to be deep enough for the barge load to pass through it without grounding itself and getting stuck. Another constraint is the locks necessary



for increasing or decreasing elevation. These locks often only support one vessel at a time and can be a point where cargo tends to get stuck for large periods of time.

- c. Performance characteristics.** Barges will travel rather slowly, only at 5 - 10 mph. This speed will be dependent on weather conditions along with waiting times at locks and dams. This makes transporting by barge very slow, however; a barge can hold the equivalent of 15 Jumbo hopper cars, and a 15 barge tow transports the equivalent of 2.25 100 Train Car Units. Barge safety is the highest among all of the possible forms of transport. This is a result of minimal water traffic, meaning that the change of injury and/or death is almost limited to within the barge itself. Barges report an average number of deaths per billion - ton miles of 0.01 and injuries per billion - ton miles of 0.09. Trains have both the highest number of injuries per billion - ton miles, 1.15, and also the highest number of injuries per billion-ton miles, 21.77. Trucks have the second most deaths per billion-ton miles, 0.84. Barges are therefore the safest option of transportation and the option with the most capacity, however; they are the slowest of the forms of transportation.
- d. Operational Impacts.** The barge system is by far the best solution for the environment, even against the tier IV trains. Barges emit much less hydrocarbons than either trains or trucks, and only about one third of the carbon monoxide and nitrous oxide that these other two forms of transportation emit. This is largely due to the efficiency of mass transportation. As the amount of cargo carried increases, the efficiency of carrying such cargo is greatly increased as well.
- e. Continuity of Operations.** One of the few downsides of the barge solution is the winter weather affecting the amount of cargo that can be moved. In winter, the sides of channels can freeze over, which can cause damage to the barge's hull. Therefore extra precautions must be taken to be sure the cargo and its crew are safe. These extra precautions can include waiting for another vessel to clear the ice from the waterway. This can cause delays, which will affect the continuity of operations. However, winter weather can affect both trains and trucks in more substantial and dangerous ways due to the fact that both rely on traction to stay safe. Therefore, barges are still the best option overall.



## **SECTION 6**    **EPA DIESEL EMISSION STANDARDS**

**6.1 Background.** In March 2008, EPA finalized a three-part program that will dramatically reduce emissions from diesel locomotives of all types, line-haul, switch, and passenger rail. The rule will cut PM emissions from these engines by as much as 90 percent and NOx emissions by as much as 80 percent when fully implemented. The standards are based on the application of high-efficiency catalytic after treatment technology for freshly manufactured engines built in 2015 and later. EPA standards also apply for existing locomotives when they are remanufactured. Requirements are also in place to reduce idling for new and remanufactured locomotives.

**6.2 Tier 0-2 Standards.** Line-haul locomotives subject to the Tier 0 through Tier 2 emission standards must also meet switch standards of the same tier. The Tier 0 standards apply for 1993-2001 locomotives not originally manufactured with a separate loop intake air cooling system. Tier 1 and Tier 2 switch locomotives must also meet line-haul standards of the same tier.

**6.3 Tier 3-4 Standards.** The switch PM standard for new Tier 2 locomotives is 0.24 g/bhp-hr until January 1, 2013, except as specified in 40 CFR Part 1033.150(a).



## **SECTION 7**    **DIESEL ENGINE EXHAUST EMISSIONS (DEEE)**

### **7.1 Diesel Emission Chemistry.**

- a. NO<sub>x</sub>.**  $N_2 + O_2 \rightarrow (NO, NO_2)$  Depending on the amount of heat delivered.
  - High temperature  $\rightarrow$  High NO<sub>x</sub>
  - Higher temperature  $\rightarrow$  Much higher NO<sub>x</sub>
- b. Particulate Matter (PM).** Particulate Matter is not a single substance, it is a process of anything collected on test filter. It focuses on oil control, wear management, and compression.
- c. CO<sub>2</sub>.**  $C_xH_y + O_2 \rightarrow CO_2 + H_2O$ 
  - $C_{in} = C_{out}$ , Fuel consumption and CO<sub>2</sub> production are directly proportional
- d. Hydrocarbons (HC).** CO<sub>2</sub> & Hydrocarbons are related because they happen in the same reaction.

**7.2 Diesel Emission Reduction Strategies.** The EPA has established the National Clean Diesel Campaign in order to promote diesel emission reduction strategies. This campaign oversees regulatory programs for new diesel engines and other innovative programs for the millions of diesel engines already in use. In the United States, heavy duty diesel retrofits have been driven primarily by subsidy programs supported under the Diesel Emissions Reduction Act, or DERA, the American Recovery and Reconstruction Act, or ARRA, Proposition 1B in California, the U.S. Department of Transportation's Congestion Mitigation and Air Quality Improvement program, or CMAQ, and other state and local programs.

### **7.3 Alternate Fuels.**

**Biodiesel (Recommended):** Biodiesel is a domestically produced, renewable fuel that can be manufactured from vegetable oils, animal fats, or recycled restaurant grease for use in diesel vehicles.

**Electricity:** Electricity can be used to power all-electric vehicles and plug-in hybrid electric vehicles.

**Ethanol:** Ethanol is a renewable fuel made from corn and other plant materials.

**Hydrogen:** Hydrogen, when used in a fuel cell, is an emissions-free alternative fuel that can be produced from diverse domestic energy sources.



**Natural Gas:** Natural gas, a domestically produced gaseous fuel, is readily available through the utility infrastructure.

**Propane:** Propane, also known as liquefied petroleum gas (LPG) or propane auto gas, has been used worldwide as a vehicle fuel for decades.

**7.4 Human Health Issues.** Epidemiological studies have demonstrated an association between different levels of air pollution and various health outcomes including mortality, exacerbation of asthma, chronic bronchitis, respiratory tract infections, ischemic heart disease and stroke. Of the motor vehicle generated air pollutants, diesel exhaust particles account for a highly significant percentage of the particles emitted in many towns and cities. This review is therefore focused on the health effects of diesel exhaust, and especially the particular matter components. Acute effects of diesel exhaust exposure include irritation of the nose and eyes, lung function changes, respiratory changes, headache, fatigue and nausea. Chronic exposures are associated with cough, sputum production and lung function decrements. In addition to symptoms, exposure studies in healthy humans have documented a number of profound inflammatory changes in the airways, notably, before changes in pulmonary function can be detected.



## **SECTION 8**    **LOCOMOTIVE FLEET UPGRADE**

**8.1 Alternatives.** The locomotives used in Pittsburgh to transport 165,000 tons of freight use diesel as the fuel source. Running diesel fuel has been confirmed to produce big amounts of nitrogen oxide (NOx), which leads to the appearance of smog and subsequently the complaints of the city residents. There's been a list of solutions proposed to this problem:

### 1) The usage of alternative fuels

**Biodiesel:** Biodiesel is a fuel made from oils/grease and animal fats. The process used to create biodiesel leaves two products: biodiesel and glycerin byproduct. The most common form of biodiesel is B20 with 20% byproduct and 80% biodiesel as it's the most efficient. Although Biodiesel results in less emission of greenhouse gases such as CO<sub>2</sub> than typical diesel, it actually emits more NOx than regular diesel. As such, switching to biodiesel wouldn't help in our mission to reduce the amount of smog in Pittsburgh.

**Natural Gas:** There are two ways in which natural gas can be: Liquefied Natural Gas (LNG) and Compressed Natural Gas (CNG). LNG is made by purifying the gas then supercooling it and creating a liquid. By contrast, CNG is made by compressing the gas to less than 1% of its volume. The usage of natural gas as a fuel would lead to less emission of NOx and thus less smog in Pittsburgh than diesel. In addition, CNG is a lot cheaper. However, there is still a cost that comes with converting the vehicle to run using this new type of fuel so it might not be the best option.

### 2) Alternative methods of shipping

Shipping by ground trucking is a way freight shipping could be done. Two methods are used: Less than Truck-load(LTL), which is used for smaller shipments, and Truck-load(TL), which is for shipments in bulk. Costs differ with each method and are determined based on the distance the truck has traveled. This method takes more time and is not as good of a shipping choice as the others.

Shipping by air is another viable option. However, this method is very costly especially as the shipments get larger. This method is very fast and effective especially in a big city like Pittsburgh despite being very costly.

Lastly, shipping by sea could be potentially considered. It can carry the largest amount at once according to ship size. However, shipping by sea takes too much time. It is typically

used for shipments that aren't time sensitive, which our problem is. If we take this route the city residents might complain, which isn't good.

### 3) Sell existing fleet and purchase new ones

Selling the existing fleet and purchasing new locomotives was proposed as a solution to meet the guidelines set by EPA. This could be very effective as it would provide us with the option to replace old, not so effective locomotives with new, efficient locomotives. GE fuel efficiency rate is expected to increase by 23% after the addition of new locomotives, which is a vast improvement. In addition, selling the existing locomotives would reduce the GE emission rate. In fact, purchasing Tier 3 will reduce PM emission by over 50% without losing any of the GE efficiency. However, investing in new locomotives costs a lot of money. Tier 3 locomotives cost around from 3-3.5 million dollars and Tier 2 locomotives sell for around 1.5 million dollars. Another drawback is the difficulty that comes with selling Tier 2 locomotives as most companies might also consider looking to sell their existing locomotives to purchase new ones.

### 4) Upgrade fleet with exhaust after-treatment hardware

Upgrading the fleet with exhaust after-treatment hardware would cause it to be more profitable. Doing so will make it more fuel efficient, leading to less cost per mile than before and thus generate more profit.

## 8.2 Existing Fleet Make-Up.

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 II -> Tier III	\$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 Tier 2 to Tier 3 locomotives is the way to go. A Tier 2 locomotive has an availability of 99.75% (which means it's available 97.55% of the time) and 22 hours of interruption per year. A Tier 3 locomotive has an availability of 99.982% and only 1.6 hours of interruption per year. That's a big improvement in the availability area. In addition, a Tier 2 locomotive has non-redundant capacity components and redundant capacity components. A Tier 3 locomotive has that in addition to dual powered equipment and multiple uplinks.

**8.5 Upgrade Schedule and Costs.** The cost of upgrading from Tier 2 to Tier 3 locomotives is \$750k per locomotive. Given GE's current fleet of 50 locomotives, that means the total cost would add up to  $750 \times 50 = \$37.5\text{million}$ .

Strategy	Cost
Tier 2 to Tier 3	\$37.5million
New Tier 3 Locomotives	\$150million
New Tier 4 Locomotives	\$200million
Alternative Fuels	\$1B and \$50million

If we were to upgrade our trains from Tier II to Tier III, we recommend an upgrade plan of upgrading locomotives in groups A, B, and C, upgrading a category over a span of 4 months. We would also recommend selling all of the locomotives in groups D and E, and purchasing new Tier III locomotives by purchasing approximately two a month until we have purchased twenty new Tier III locomotives by October 2016. If this schedule is followed all fifty of our Tier II locomotives would then be Tier III locomotives by the end of 2016.



## **SECTION 9      SUMMARY**

In response to the issue of aging trains for the shipment of goods in and out of Pittsburgh, this group chose to have the trains replaced by barges because doing so will cost less than upgrading the trains or replacing them with trucks, as well as being a safer option. In addition, many of the roads and bridges in Pennsylvania were inspected and were found to be structurally deficient and are in need of maintenance (both of them scored a D- in quality). The Pennsylvania Inland Water Ways scored a D+, and the railway systems scored a B which cements its place as the most reliable form of transportation of the three.

Epidemiological studies have demonstrated an association between different levels of air pollution and various health outcomes including mortality, exacerbation of asthma, chronic bronchitis, respiratory tract infections, ischemic heart disease and stroke. Diesel exhaust particles account for a very high percentage of the air pollution. In addition, running diesel fuel has also been confirmed to produce NOx, which leads to the emission of smog. The appearance of smog has been the subject of complaint from Pittsburgh city residents. Tier 2 locomotives that are used to haul freight are approaching age for overhaul, and will need to meet the EPA Tier 3 or higher requirements as new regulations apply with the goal of reducing emissions. The solutions that were proposed to this problem include the usage of alternative fuels like Biodiesel and Natural Gas, switching to alternative methods of shipping like shipping by ground, air, or sea, and selling existing fleet and purchasing new ones (upgrading). The strategy that was ultimately selected was the selling of all trains and purchasing 15 barges with the money acquired through the sale. This was selected due to the low environmental damage that barges cost, their superior fuel efficiency compared to trains, and their extremely low cost of transportation. With such a low cost of transportation, money will be saved that was otherwise spent, this money saved can lead to expanding our fleet of barges, increasing our overall freight transportation capacity and our transportation times.



## **SECTION 10    REFERENCES**

[http://kentuckyriverports.com/water\\_transport\\_benefits/](http://kentuckyriverports.com/water_transport_benefits/)

<http://business.tenntom.org/why-use-the-waterway/shipping-comparisons/>

<http://www3.epa.gov/otaq/locomotives.htm>

[http://www.cdti.com/content/americas/applications/diesel\\_engines.htm](http://www.cdti.com/content/americas/applications/diesel_engines.htm)

<http://www.afdc.energy.gov>

EDSGN100\_DP2\_GE Presentation\_F2015.pdf

<http://www.ncbi.nlm.nih.gov/pubmed/11401072>

<http://www.cyberciti.biz/faq/data-center-standard-overview/>

<https://www.dieselnets.com/standards/us/loco.php#tier3>

<https://www.ovh.com/us/dedicated-servers/understanding-t3-t4.xml>

<https://www.dieselnets.com/standards/us/nonroad.php>

<http://pareportcard.org/index.php>

Estimating Transport Costs.pdf

PA\_2014\_RC\_Bridges.pdf

PA\_2014\_RC\_Roads.pdf

PA\_2014\_RC\_Inland\_Waterways.pdf

PA\_2014\_RC\_Rail.pdf



Figure 1: Standard Large Diesel Truck with Trailer



Figure 2: Diesel Locomotive



Figure 3: Typical Railway Hopper Car





Figure 4: Typical Railway Refrigerator Car



Figure 5: Typical Box Car





Figure 6: Typical Tank Car



Figure 7: Inland Water Barge with Tug



Figure 8: Inland Waterway System with Lock and Dam





Figure 9: Pennsylvania Bridges in Disrepair



Figure 10: Typical Pennsylvania Roads



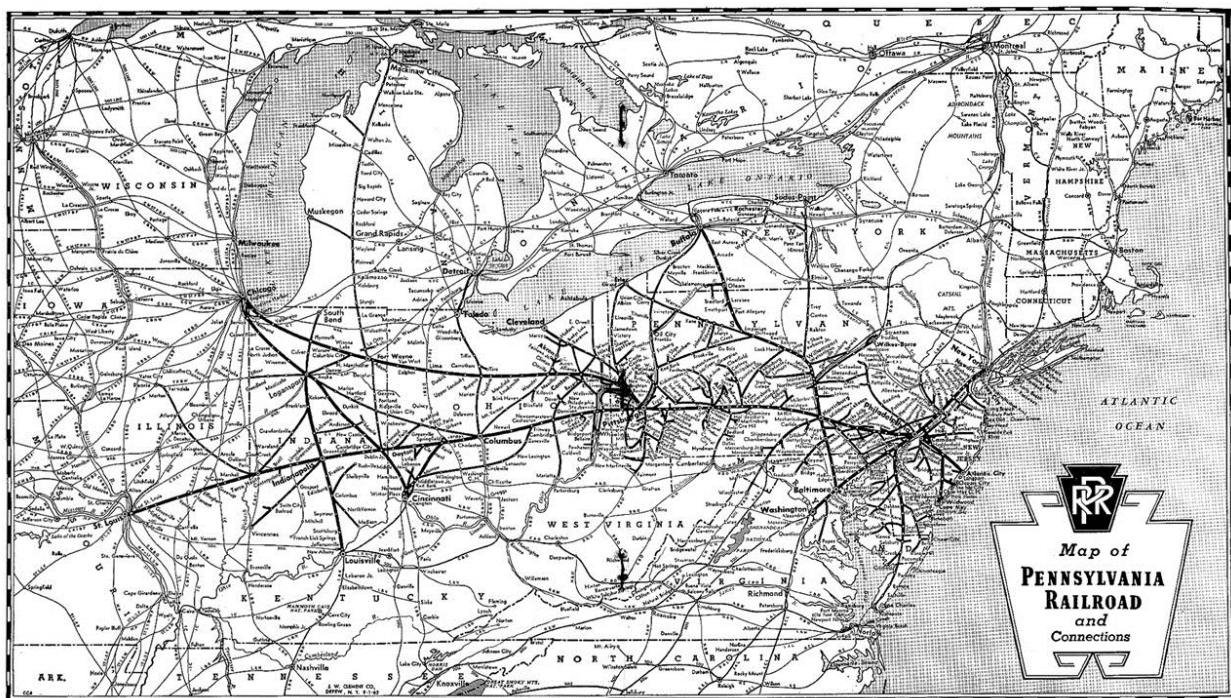
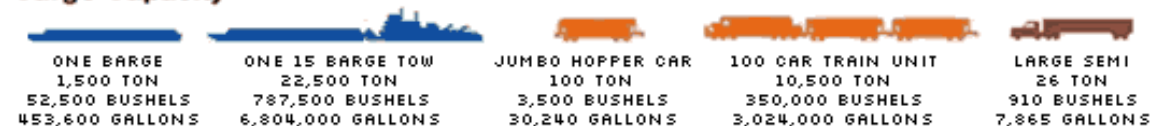


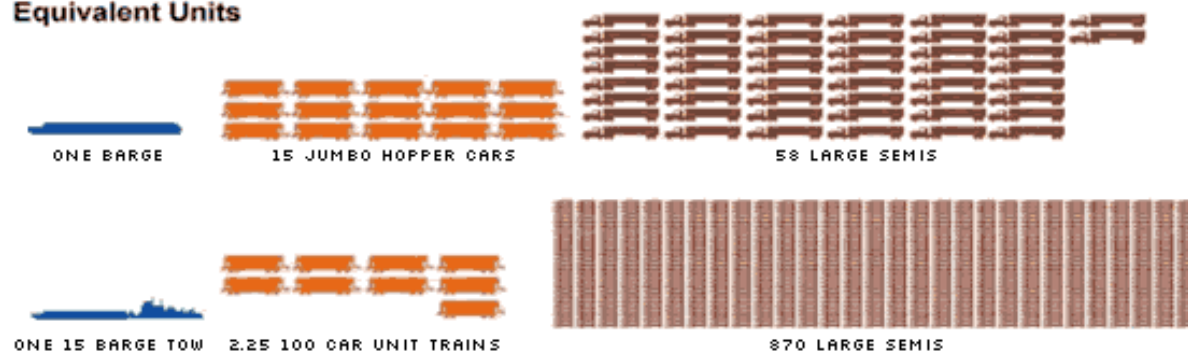
Figure 11: Pennsylvania Railroads

# Compare...

## Cargo Capacity



## Equivalent Units



## Equivalent Lengths



Figure 12: Capacity, Equivalent Units and Lengths