The Pennsylvania State University
University Park Campus

Freight, Fuel, & Emissions

GE Transportation

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Section 001

Design Team 6
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SECTION 1 EXECUTIVE SUMMARY

This report contains the information about the best solution to the problem presented by GE, to limit emissions and cost of transportation using locomotives. Enclosed, there is information regarding transportation costs, efficiencies, consumer choices and emissions of the three major types of transportation, trucks, trains and barges. This will focus on transportation using trains, because it is the most efficient of the three. Information of the other options capacities and costs will be provided, along with other fuel options. That information will show how the final best solution was determined. The main problem with locomotive trains now is their exhaust is very bad for the environment. Throughout the report, information regarding upgrades of the locomotives shows how we recommend that GE reduce their exhaust emissions.

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 Pittsburg, approx. 165,000 tons of freight or minerals (coal, etc.) per day travel via rail. Smog from locomotive emissions is a key complaint of 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.

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 emissions and regulations, cost, capacity, public opinion, and on time delivery.

2.5 Project Freight Requirements.

Approximately 165,000-tons of freight or minerals (coal, etc) per day travel in or out of the port city of Pittsburg via rail.

2.6 Transportation Mode Comparisons.

a. Trucks.

Dimensions: 53 feet long, 8½ feet wide, and 13½ feet tall.
Capacity: 22 tons.
Pros: Transportation by truck allows for a very flexible schedule and allows for route branching.
Cons: Low capacity means more trips, which correlates to more emissions given per ton of cargo transported. Truck transport also requires more staffing per ton of cargo.

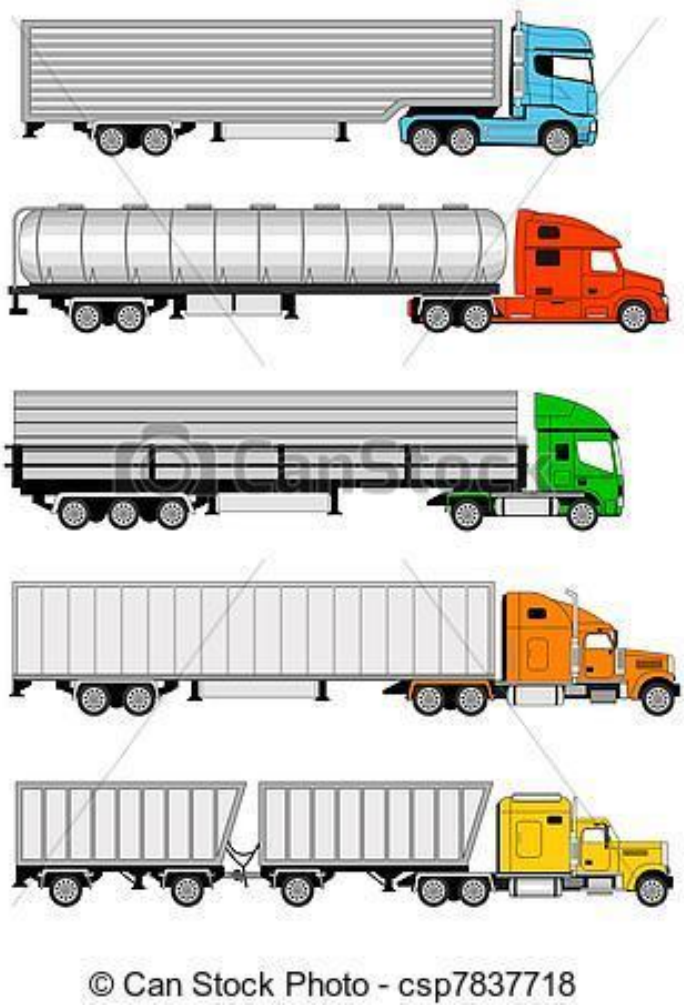


Figure 1: Types of trucks used to transport cargo

b. Barges.

Dimensions: 290 feet long and 50 feet wide
Capacity: 1500 tons
Pros: High capacity allows for more cargo transported per trip, which in turn helps to limit emissions per ton of cargo shipped.
Cons: Limited time frame and very limited routes which a barge can take. This may limit the timeliness of delivery.

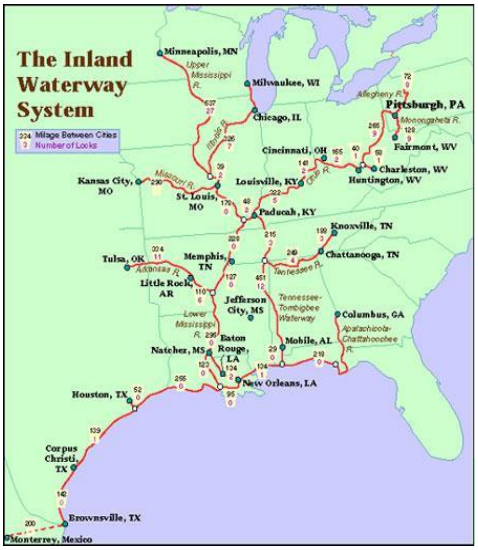


Figure 3: Inland waterway system in the Eastern U.S.

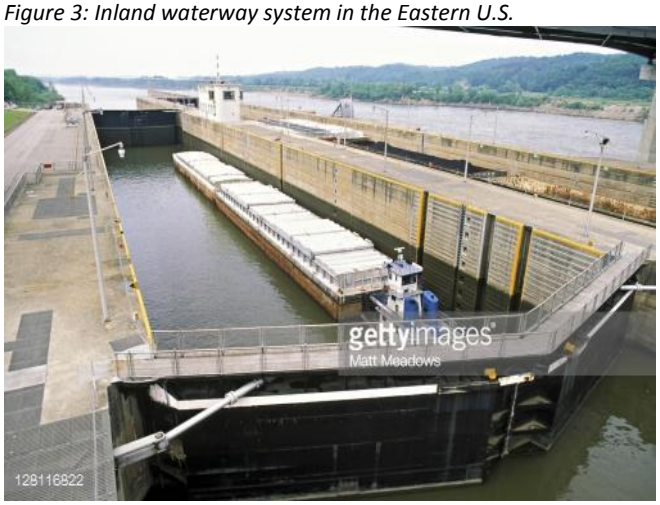


Figure 4: A typical river lock used to transfer barges between river levels

c. Railroad.

Dimensions (Individual car. Train consist of 50 cars.): 60 feet long, 20 feet wide, and 15 feet tall
Capacity (Individual, Train): 105 tons, 5250 tons
Pros: Huge capacity per trip. Creates less emissions than truck transport.
Cons: Limited routes may limit timeliness. Rail transport is not as environmentally friendly as barge transport.

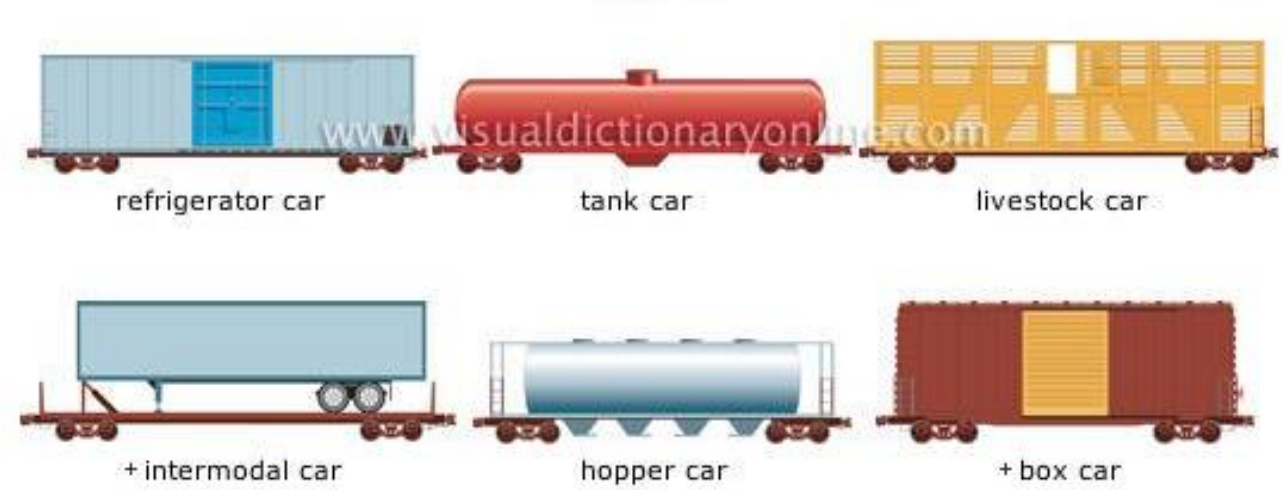


Figure 5: Types of rail cars

Figure 6: A typical train. As you can see, one locomotive can pull many cars.

SECTION 3 TRANSPORTATION INFRASTRUCTURE CONDITION AND CAPACITY

3.1 Introduction.

Infrastructure also moves our economy taking goods from ports to roads to store shelves and moves workers from their homes to their workplace. In fact, Pennsylvania's roads carry 34% more goods across the Commonwealth than the average state making it critical that roads and bridges are able handle the loads and keep us moving. When looking at Pennsylvania's report card, Pennsylvania's bridges were rated at a D+, its roads were rated at a D-, and its Freight Rale was rated at a B. Overall, Pennsylvania's infrastructure is one of the most deficient in the country. This is not because of neglect or poor engineering, but because of the tremendous wear that Pennsylvania's infrastructure withstands. [See Figure 1]

3.2 Pennsylvania Roads and Bridges.

Of Pennsylvania's more than 22,660 bridges, 23 percent are considered structurally deficient, which is the highest percentage in the nation.[See Figure 2] The Commonwealth's bridges are 10 years older than the national average and are in dire need of repair and modernization. The economy and the quality of life in the Commonwealth of Pennsylvania (the Commonwealth) require a transportation system that provides a safe, reliable and efficient driving environment. The Commonwealth's transportation system includes over 22,660 bridges, the third highest number of bridges in the nation, and over 114 million drivers pass over these bridges every day.

3.3 Pennsylvania Inland Waterways.

Pennsylvania's inland waterway infrastructure, which connects the Commonwealth to the national waterway system, was built over the last 150 years. Many of its locks and dams are in a severe state of disrepair due to lack of maintenance and capital improvements funding over several decades. The grade of D+ reflects the fact that none of Pennsylvania's navigation dams and only 18 percent of the locks have a "satisfactory" condition assessment rating, and delays at the most degraded facilities are frequent.[See Figure 3] Pittsburgh has been named the start of the Federal Marine Highway No. M-70, extending all the way to Kansas City and connecting with the Mississippi River (M-55) and the IntraCoastal Waterway (M-10), according to MARAD's Marine Highway Program. This Marine Highway corridor has the potential to help alleviate a portion of the congestion from the existing landside routes, while at the same time reducing emissions, conserving energy, improving safety ,and reducing highway maintenance costs. It can also contribute to increased economic and commercial activity in the region by removing barriers to efficient freight transportation.

3.4 Pennsylvania Freight Rail System.

Pennsylvania has 57 freight railroads covering 5127 miles across the state, ranking it 4th largest rail network by mileage in the U.S. By 2035, 246 million tons of freight is expected to pass through the Commonwealth of Pennsylvania, an increase of 22 percent over 2007 levels.[See Figure 4] Pennsylvania railroad freight demand continues to exceed current infrastructure. Railroad traffic is steadily returning to near- World War II levels, before highways were built to facilitate widespread movement of goods by truck. Pennsylvania is one of the nation's leaders in freight assessment, planning, and investment spurring from the Commonwealth's industrial heritage. Today, most railroads are privately owned. Class I and mid-sized railroads operating within the Commonwealth's borders are generally able to finance their own capital improvements. In addition to the larger railroads, the regional and short line railroads are the feeders and supporting players in Pennsylvania's overall transportation network. Problems arise with short line railroads, which have difficulty in making infrastructure investments to remain viable and competitive.

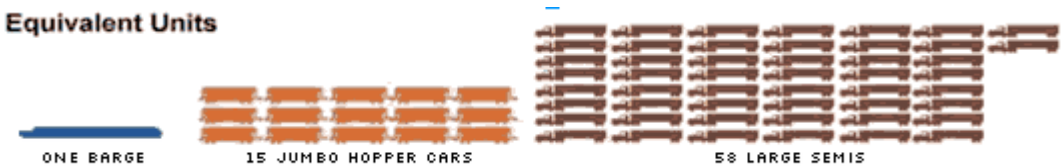
SECTION 4 STANDARD CAPACITY FOR ALTERNATE TRANSPORTATION MODES

4.1 Cargo Capacity.

Alternate modes of transportation include a barge, one 15 barge tow, one bulk type railroad car, one boxcar type railroad car, and one highway truck trailer. A barge can haul 1500 tons, a 15 barge tow can haul 22,500 tons, a bulk type railroad car can haul up to 100 tons, a boxcar type railcar can haul 50 tons and a highway truck trailer can haul up to 26 tons.

4.2 Equivalent Units.

Barges have the greatest hauling capacities in comparison to bulk sized rail cars and especially over highway truck trailers. For example, a barge can haul 15x what a bulk type railcar can carry. It can also haul 58x what a highway truck trailer can.



4.3 Equivalent Lengths.

Barges can not only carry the most, they are also the shortest per capacity. Rail cars and highway truck trailers are shorter individually, but with the same capacity, barges are only 0.25 miles long. A train of railcars that could haul that amount would be 2.75 miles long, and there would need to be 11.5 miles of truck trailers lined up to meet that capacity.

SECTION 5 TRANSPORTATION COSTS AND CONCEPT OF OPERATIONS (ConOps)

5.1 Trucks.

Overall, in 1994 TL general freight trucking had a per-mile operating cost of $1.25, **a cost per ton-mile of 8.42 cents, and an average load of 14.80 tons.** Take a look at f**igure 5. a and b** for addition costs.

5.2 Barges.

Barges have a lot of different options of how to ship and at what size etc. Things like the type of vessel, what voyage and port, cargo related and physical dimensions, insurance, repair , crew, and fuel all affect the price in someway or another. But according to Cambridge Systematic, Inc Appendix F the prices **range anywhere from .09 cents per ton per mile to about 8 cents per ton per mile.** See **figure 7** for addition prices.

5.3 Railroad.

According to Cambridge Systematic, Inc Appendix F: In total the cost in All Commodities **3.034 cents per ton per mile.** See **figure 5.a and 6** for most detailed analysis.

5.4 Most Economical Transportation Solution.

Truck Trailers can carry as much as trains, but to get the same output it would take ten times the amount of energy. As seen in Figure XXXXX the cost per ton-mile of freight is much lower than trucking, but it is still higher than barges. Barges are the most economically efficient way of transporting goods. Although barges are the most economically efficient, they are not the best solution. The best solution is all trains due to other combining factors mentioned later in the report.

5.5 Concept of Operations (ConOps).

a. General Description.

The basic proposal keeps rail as the only method of transport. The freight capacity of the new system will be of the same capacity as is would be initially, as all 50 trains will be kept in service. It is proposed that the ten oldest locomotives will be sold and replaced by 10 new Tier IV locomotives. The remaining 40 locomotives will be upgraded from Tier II to Tier III. All trains will operate as they have operated initially.

b. Operational Policies and Constraints.

All operations will remain unchanged after all upgrades have been made. Trains will run on their normal schedules with the same amount of staffing.

c. Performance characteristics.

In regards to transportation system speed, capacity, reliability, safety and security, virtually no change will occur before and after the proposed plan.

d. Operational Impacts.

Since all trains will be upgraded to higher Tier III or Tier IV, the environment will benefit from the drastic improvement in reduced emissions.

e. Continuity of Operations.

During extreme conditions, barges cannot be used. They cannot operate when there is ice in the water, and they cannot be operated when it is so hot that the rivers are too low. Truck trailers can operate through all conditions, but they can be delayed or temporarily stopped in certain extreme conditions. Trains can be operated in any conditions, heat or even ice and snow. That is why trains are the best solution because they can be used year round in all locations.

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.

Tier 0-2 standards: The first emission regulation for railroad locomotives was adopted on 17 December 1997. The rule making, which became effective from 2000, applies to locomotives originally manufactured from 1973, any time they are manufactured or remanufactured. Tier 0-2 standards are met though engine design methods, without the use of exhaust gas after treatment.

Tier 3-4 standards: A regulation signed on 14 March 2008 introduced more stringent emission requirements. Tier 3 standards, to be met by engine design methods, become effective from 2011/12. Tier 4 standards, which are expected to require exhaust gas after treatment technologies, become effective from 2015.

6.2 Tier 0-2 Standards.

Table 1
Tier 0-2 Locomotive Emission Standards, g/bhp·hr

Duty Cycle	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	7.4	0.45
Switch	1.2	2.5	11.0	0.54
Tier 2 (2005 and later)				
Line-haul	0.3	1.5	5.5	0.20
Switch	0.6	2.4	8.1	0.24
Non-Regulated Locomotives (1997 estimates)				
Line-haul	0.5	1.5	13.5	0.34
Switch	1.1	2.4	19.8	0.41

* HC standard is in the form of THC for diesel engines

Table 2
Locomotive Smoke Standards, % opacity (normalized)

	Steady-state	30-sec peak	3-sec peak
Tier 0	30	40	50
Tier 1	25	40	50
Tier 2 and later	20	40	50

6.3 Tier 3-4 Standards.

Tier 3 standards—Near-term engine-out emission standards for newly built and remanufactured locomotives. Tier 3 standards are to be met using engine technology.

Tier 4 standards—Longer-term standards for newly built and remanufactured locomotives. Tier 4 standards are expected to require the use of exhaust gas after treatment technologies, such as particulate filters for PM control, and urea-SCR for NOx emission control.

Table 4
Switch Locomotive Emission Standards, g/bhp·hr

Tier	MY	Date	HC	CO	NOx	PM
Tier 0	1973-2001	2010[b]	2.10	8.0	11.8	0.26
Tier 1[a]	2002-2004	2010[b]	1.20	2.5	11.0	0.26
Tier 2[a]	2005-2010	2010[b]	0.60	2.4	8.1	0.13[c]
Tier 3	2011-2014	2011	0.60	2.4	5.0	0.10
Tier 4	2015 or later	2015	0.14[d]	2.4	1.3[d]	0.03

a - Tier 1-2 switch locomotives must also meet line-haul standards of the same tier.
b - As early as 2008 if approved engine upgrade kits become available.
c - 0.24 g/bhp-hr until January 1, 2013 (with some exceptions).
d - Manufacturers may elect to meet a combined NOx+HC standard of 1.3 g/bhp-hr.

Table 3
Line-Haul Locomotive Emission Standards, g/bhp·hr

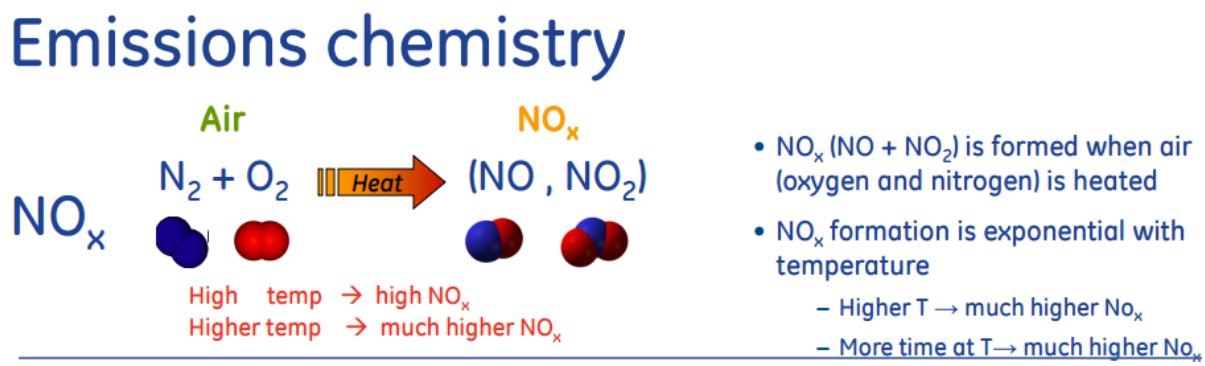
Tier	MY	Date	HC	CO	NOx	PM
Tier 0[a]	1973-1992[c]	2010[d]	1.00	5.0	8.0	0.22
Tier 1[a]	1993[c]-2004	2010[d]	0.55	2.2	7.4	0.22
Tier 2[a]	2005-2011	2010[d]	0.30	1.5	5.5	0.10[e]
Tier 3[b]	2012-2014	2012	0.30	1.5	5.5	0.10
Tier 4	2015 or later	2015	0.14[f]	1.5	1.3[f]	0.03

a - Tier 0-2 line-haul locomotives must also meet switch standards of the same tier.
b - Tier 3 line-haul locomotives must also meet Tier 2 switch standards.
c - 1993-2001 locomotive that were not equipped with an intake air coolant system are subject to Tier 0 rather than Tier 1 standards.
d - As early as 2008 if approved engine upgrade kits become available.
e - 0.20 g/bhp-hr until January 1, 2013 (with some exceptions).
f - Manufacturers may elect to meet a combined NOx+HC standard of 1.4 g/bhp-hr.

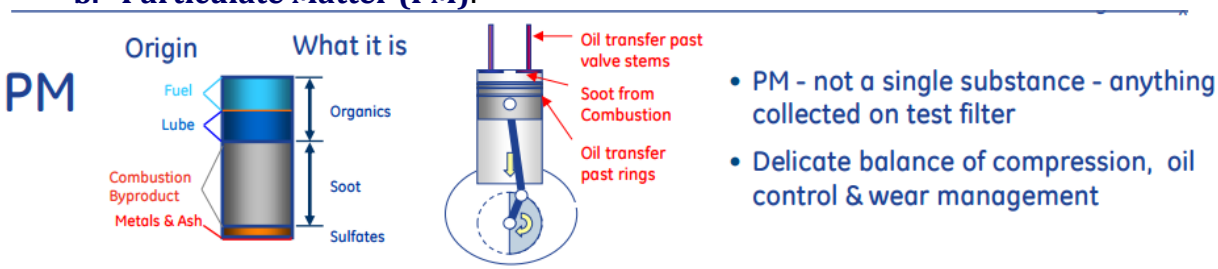
SECTION 7 DIESEL ENGINE EXHAUST EMISSIONS (DEEE)

7.1 Diesel Emission Chemistry.

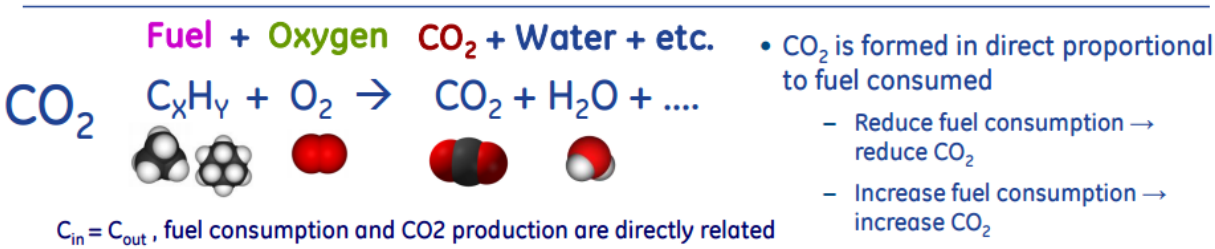
a. NOx.



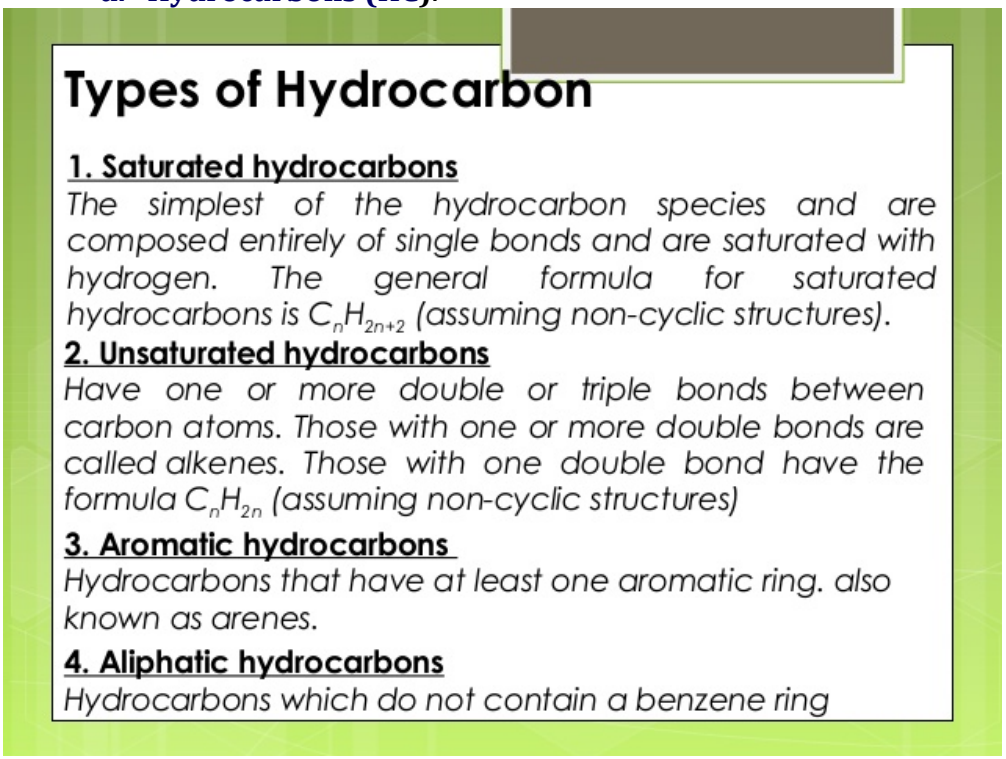
b. Particulate Matter (PM).



c. CO_2.



d. Hydrocarbons (HC).



7.2 Diesel Emission Reduction Strategies.

Certain strategies that could be put in place in order to reduce diesel emissions would be to ensure the implementation of Tier 4 locomotives which have much stricter emission standards. Another strategy would be to upgrade any and all Tier 2 locomotives to Tier 3, which although their emission standards are not to the degree of Tier 4, are far superior to that of Tier 3.

7.3 Alternate Fuels.

After reviewing the cost versus the benefit of researching and possibly utilizing alternative fuels, it was collectively decided not to invest in alternate fuel sources. When looking at how expensive not only the research, but also the implementation of alternate fuels, we decided the benefits provided by moving away diesel fuel(s) just doesn't outweigh the tremendous cost of alternate fuels.

7.4 Human Health Issues.

This assessment examined information regarding the possible health hazards associated with exposure to diesel engine exhaust (DE), which is a mixture of gases and particles. The assessment concludes that long-term (i.e., chronic) inhalation exposure is likely to pose a lung cancer hazard to humans, as well as damage the lung in other ways depending on exposure. Short-term (i.e., acute) exposures can cause irritation and inflammatory symptoms of a transient nature, these being highly variable across the population. The assessment also indicates that evidence for exacerbation of existing allergies and asthma symptoms is emerging. The assessment recognizes that DE emissions, as a mixture of many constituents, also contribute to ambient concentrations of several criteria air pollutants including nitrogen oxides and fine particles, as well as other air toxics. The assessment's health hazard conclusions are based on exposure to exhaust from diesel engines built prior to the mid-1990s. The health hazard conclusions, in general, are applicable to engines currently in use, which include many older engines. As new diesel engines with cleaner exhaust emissions replace existing engines, the applicability of the conclusions in this Health Assessment Document will need to be reevaluated.

SECTION 8 LOCOMOTIVE FLEET UPGRADE

8.1 Alternatives.

i. Sell existing fleet and purchase new locomotives
   a. Each new locomotive costs $4M
   b. Can sell used locomotives for $1.5M
   c. New locomotives will be Tier IV, which will create much less emissions
ii. Upgrade fleet with exhaust after-treatment hardware
   a. Each upgrade costs $750k
   b. Upgraded locomotives will be Tier III
iii. Utilize alternate fuels (Biodiesel, CNG, LNG, etc.) which may produce less NOx
   a. Each locomotive upgrade costs $1M
   b. Adding a new fueling station costs $1B
   c. This option would greatly limit emissions, however, it was considered too costly to be implemented currently

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.

The recommended strategy involves buying new Tier IV locomotives as well as upgrading some of the existing locomotives to Tier III. It was decided that buying Tier IV instead of Tier III would be worth the extra $1M per locomotive, since Tier IV produces far less emissions than Tier III. Upgrading the entire fleet seems unwise since a large portion of the locomotives still have potential mileage before they need to be retired. With this logic in mind, all locomotives in group E (highest mileage group) should be sold and replaced with new Tier IV locomotives. The rest of the fleet (groups A-D) should be upgraded to Tier III. It was decided to not utilize alternative fuels because of the high cost of this upgrade, although this may be a viable solution in the future when they become more affordable.

8.5 Upgrade Schedule and Costs.

2016 - Sell 10 used locomotives for $1.5M each: **$15M**

2016 - Buy 10 new Tier IV locomotives at $4M each: **$40M**

2017-2021 - Upgrade remaining 40 locomotives to Tier III at $750k each: **$30M**

Total Cost: ($40M + $30M) – ($15M) = **$55M**

SECTION 9 SUMMARY

As seen in the report, there are three main types of transportation: barge, rail car, and truck trailer. All three ways have their advantages and disadvantages. As seen above, transportation by rail car is the cheapest per mile per ton. Barges have the best economic output and can haul a very large capacity in comparison to truck trailers and rail cars, but barges have many faults. Pennsylvania is not known for shipping with barges, because it is landlocked and does not have many stable rivers connecting major cities. In the winter, the water tends to freeze over in most of the state, and even the country, which would put transportation to a hold. Truck trailers are a better way because they can run all year round and they aren't large so they can transport anywhere to any city. Truck trailers are the most expensive and they also can't carry anywhere their capacity of a rail car or barge. Rail cars came out on top as the best form of transportation to the city of Pittsburgh. They are in the middle for most categories and have the best overall efficiency out of the three modes of transportation.

Deciding to ship with just rail cars was the first part, but the second part was determining how to limit and eliminate the emissions of them. The locomotives that pull the rail cars produce a lot of waste, and GE found a way to limit that waste. They created a Tier 4 Locomotive that would cut the emissions even more than the tier 3. The two ways to get these locomotives are to sell old ones and buy new ones, or to upgrade existing tier 2 locomotives to tier 3. The tier 2 locomotives are too out of date and are not environmentally efficient enough, so all trains must be up to tier 3. It is cheaper to upgrade them to tier 3 rather than buying a new tier 3 or 4. They do not last forever, so at some point it is better to just sell them and buy brand new tier 4 locomotives. When buying a new one, rather than spending $3 million on a new tier 3, the better solution would be to buy a tier 4. The best solution found is to sell the 10 locomotives with the most mileage on them and to buy 10 new tier 4 ones. The rest will then be upgraded from tier 2 to tier 3. This solution is the most economically efficient because there is no need to spend all the money buying new trains when most can be upgraded to the efficiency needed for a small portion of the price. Rather than buying 50 new tier 3 or 4 locomotives, upgrading the ones that have few miles on them would be the best solution.

SECTION 10 REFERENCES

- http://www.glostone.com/wp-content/uploads/2012/09/ATRI-Operational-Costs-of-Trucking-2012.pdf
- https://books.google.com/books?id=WkEzAQAAMAAJ&pg=PA152&lpg=PA152&dq=train+locomotive+scrap+cost&source=bl&ots=JbQHHDWBG8&sig=a_aMwZAzBM91GnIFE5FhOMRSiXI&hl=en&sa=X&ved=0CFsQ6AEwCmoVChMImv231MqNyQIVgyYmCh0QhAf-#v=onepage&q=train%20locomotive%20scrap%20cost&f=false
- http://business.tenntom.org/why-use-the-waterway/shipping-comparisons/
- https://www.dieselnet.com/standards/us/nonroad.php
- http://grist.org/article/freight-trains-19th-century-technology-due-for-a-21st-century-revival/

Figure 1a&b: Typical Diesel Truck and Trailer.

Figure 2a and 2b. Typical Diesel-Electric locomotive.

Figure 3a&b: Typical Inland Water Ways Barge and Tug.

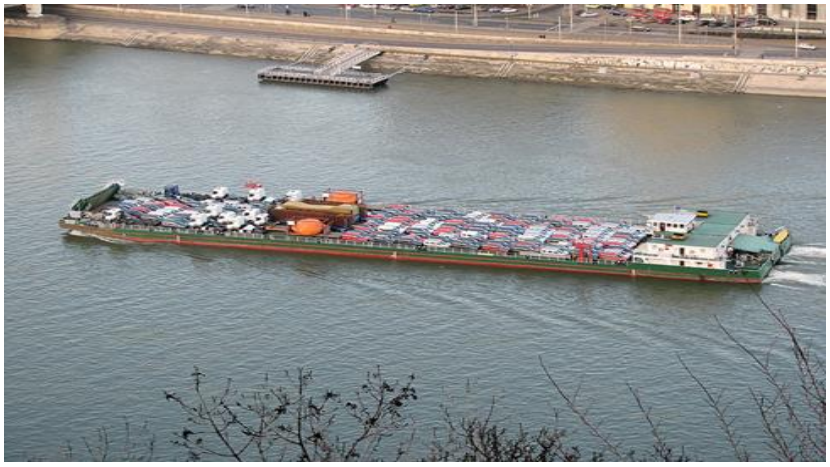


Figure 4a&b: Comparison of the three different types of shipping

Mode of Transportation	Tons of Cargo	Bushels of Cargo	Gallons of Cargo
One Barge	1,500 tons	52,500 bushels	453,600 gallons
One Rail Car	100 tons	3,500 bushels	30,240 gallons
100-car Train Unit	10,000 tons	350,000 bushels	3,024,000 gallons
Large Semi	26 tons	910 bushels	7,865 gallons

Figure 5a

Table 2–1. Private operating costs of truckload (TL) general freight trucking, 1994 (thousands of 1994 dollars)

Expense category	Length of haul: Under 250 miles	250 to 500 miles	Over 500 miles	All TL general freight carriers
Salaries	46,886	79,729	298,930	425,546
Wages	297,525	358,887	1,939,752	2,596,164
Fringes	94,755	87,227	391,724	573,706
Operating supplies	158,493	275,786	1,284,868	1,719,148
General supplies	39,024	73,156	356,455	468,635
Tax and license	31,238	45,345	329,234	405,827
Insurance	40,743	60,480	316,131	417,354
Utilities	12,525	21,188	100,546	134,259
Depreciation	51,963	80,938	458,853	591,754
Equipment rents	322,098	689,313	2,655,641	3,667,052
Office equipment	5,523	15,472	45,125	66,120
Disposal of assets	(2,516)	(8,905)	(30,218)	(41,639)
Miscellaneous	13,800	27,606	73,231	114,637
Total expenses	1,112,057	1,806,233	8,220,271	11,138,562
Highway miles operated (thousands)	723,052	1,367,380	6,845,397	8,935,829
Ton-miles (thousands)	5,252,908	20,198,788	106,832,649	132,284,345
Cost per mile (dollars)	1.54	1.32	1.20	1.25
Cost per ton-mile (cents)	21.17	8.94	7.69	8.42
Average load (tons)	7.26	14.77	15.61	14.80

SOURCE: ATA (1995, Summary Tables III and V).

Figure 5 b

Table 3–15. Summary of external costs of truck and rail freight (1994 cents per ton-mile)

	Accidents	Air pollution*	Greenhouse gases	Noise	Total
General freight truck	0.59	0.08	0.15	0.04	0.86
Heavy unit train	0.17	0.01	0.02	0.04	0.24
Mixed freight train	0.17	0.01	0.02	0.04	0.24
Intermodal train	0.17	0.02	0.02	0.04	0.25
Double-stack train	0.17	0.01	0.02	0.04	0.24

* Totals from Tables 3–9 and 3–11 rounded to two decimal places.

Figure 6

Exhibit F.3 Average Rail Rates per Ton-Mile for Selected Commodity Groups

STCC Code and Commodity Group		Cents per Ton-Mile (1992 Dollars)
01	Farm Products	2.19¢
11	Coal	2.10
14	Nonmetallic Minerals	2.98
20	Food Products	2.92
24	Lumber and Wood Products	2.89
26	Pulp and Paper Products	3.93
28	Chemical Products	3.90
29	Petroleum and Coal Products	4.03
32	Clay, Concrete, Glass, and Stone Products	3.59
33	Primary Metal Products	3.18
37	Transportation Equipment	9.01
40	Waste and Scrap Materials	3.83
42	Empty Shipping Containers	3.83
46	Miscellaneous Mixed Freight	2.91
All Commodities		**3.03¢**

Figure 7

Exhibit F.4 Deep-Draft Vessel Costs (1995 dollars)

Capacity (DWT Tons)	Speed (Knots)	U.S. Flag Dollars per Hour	U.S. Flag Cents per Ton-Mile[1]	Foreign Flag Dollars per Hour	Foreign Flag Cents per Ton-Mile[1]
Tanker – Non-Double Hull					
20,000	14	$1,592	1.184¢	$639	0.475¢
50,000	14	1,953	0.581	815	0.243
90,000	14	2,270	0.375	975	0.161
150,000	14	2,625	0.260	1,162	0.115
265,000	14	3,128	0.176	1,440	0.081
Tanker – Double Hull					
20,000	14	$1,452	1.080¢	$583	0.434¢
50,000	14	1,981	0.589	826	0.246
90,000	14	2,519	0.417	1,075	0.178
150,000	14	3,185	0.316	1,386	0.138
265,000	14	4,228	0.237	1,880	0.106
Dry Bulk					
15,000	14	$1,093	1.084¢	$393	0.390¢
40,000	14	1,430	0.532	561	0.209
80,000	14	1,820	0.339	759	0.141
120,000	14	2,136	0.265	820	0.114
200,000	14	NA	NA	1,204	0.090
General Cargo					
11,000	17	$1,059	1.259¢	$412	0.490¢
20,000	17	1,393	0.910	542	0.354
30,000	17	1,721	0.750	667	0.291
Container					
Capacity (TEUs)	Speed (Knots)	Dollars per Hour	Cents per TEU-Mile	Dollars per Hour	Cents per TEU-Mile
600	17	$909	14.85¢	$544	8.88¢
1,200	17	1,154	9.43	768	6.28
2,000	18	1,517	7.02	1,101	5.10
2,800	19	1,984	6.22	1,527	4.78
4,000	20	2,293	4.78	1,811	3.77