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Freight, Fuel, & Emissions

GE Transportation

EDSGN 100

Section 001

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SECTION 1 EXECUTIVE SUMMARY

Pittsburgh needs a more eco-friendly alternative to the current method of transportation for freight. Freight transportation needs to meet current EPA requirements in order to reduce smog and to protect human and environmental health. In addition to meeting health requirements, new transportation methods must maintain or increase the capacity of freight.

To meet the environmental goal, the proposal is to reduce the fleet size to 40 locomotives that meet tier 4 emission standards. This goal will improve GE transportation by reducing the environmental impact. Simultaneously, the capacity of freight will be maintained at 165,000 tons a day.

To meet the economic goal, the size of the fleet is being reduced and only locomotives, the most advantageous transportation method, are being used. The upgrade to tier 4 emission standards will be costly, but will be offset by the reduction of fleet size and the sole use of locomotives.

The solution to current freight transportation issues is to meet the 2015 tier 4 emission standards with a smaller fleet. The smaller fleet size will have approximately 2-year return on investment and will greatly reduce diesel emissions.

SECTION 2 INTRODUCTION

2.1 Project Objectives. Plan the most efficient method to move 165,000 tons of freight in and out of Pittsburgh via rail, truck, or barges. EPA standards are a major consideration as well as cost.

2.2 Project Background. Pittsburgh transports a majority of its freight by rail. This has led to a number of issues, such as smog. Not only is the smog an issue, but the age of the trains are reaching inhibitive levels. The city would benefit by an increase in freight capacity, which is being considered.

2.3 Project Sponsor Background. GE Transportation is sponsoring this project. Headquartered in Chicago, Illinois, the company has been in business for over one hundred years. It boasts a multinational team of 13,000 members and has over sixty-five sites worldwide.

2.4 Project Description.

Conduct 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 have to be considered. Also, detailed explanations for the points below have to be included in the recommendations.

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

2.5 Project Freight Requirements.

Ensure that the upgraded locomotive fleet meets the recent emissions guidelines set by EPA. Also, the solution must be cost-effective while maintaining the freight capacity or find out if there is any possible ways to increase the freight capacity and at the same achieves all requirements set by EPA.

2.6 Transportation Mode Comparisons.

Type of transportation	Speed	Reliability	Flexibility	Distance
Trucks	Moderate	Good	High	Short and Medium
Barges	Slow	Limited	Low	Medium and Long
Rail road	Moderate	Good	Low	Medium and Long

a. Trucks.

Whitenies Blog states that,

"Advantages of Trucks:

1) It provides a complete "door-to-door" service.

2) It can be cheaper than other modes of transportation for short hauls (less than 400 miles or 640 km).

3) It can be cheaper for small shipments regardless of distance.

4) It can be faster on short hauls.

5) It can provide frequent service.

6) It is highly flexible, able to go wherever there are roads and streets.

7) It offers a wide variety of equipment.

8) The freight can be loaded and unloaded quickly.

Disadvantages of Trucks:

1) It is more expensive for long hauls than some competing modes of transit

2) It is too expensive for many low-grade and bulk commodities in intercity service

3) It is limited somewhat as to what it can carry by the size of the vehicles used and by size and weight restrictions imposed by states

4) It is affected by weather and road conditions and traffic."

b. Barges.

Advantages of Barges:

1. Low Cost:

Rivers are a natural highway which does not require any cost of construction and maintenance. Even the cost of construction and maintenance of canals is much less or they are used, not only for transport purposes but also for irrigation, etc. Moreover, the cost of operation of the inland water transport is very low. Thus, it is the cheapest mode of transport for carrying goods from one place to another.

2. Larger Capacity:

It can carry much larger quantities of heavy and bulky goods such as coal, and, timber etc.

3. Flexible Service:

It provides much more flexible service than railways and can be adjusted to individual requirements.

Disadvantages of Barges:

1. Slow:

Speed of Inland water transport is very slow and therefore this mode of transport is unsuitable where time is an important factor.

2. Limited Area of Operation:

It can be used only in a limited area that is served by deep canals and rivers.

3. Seasonal Character:

Rivers and canals cannot be operated for transportation throughout the year as water may freeze during winter or water level may go very much down during summer.

4. Unreliable:

The inland water transport by rivers is unreliable. Sometimes the river changes its course, which causes dislocation in the normal route of the trade.

5. Unsuitable for Small Business:

Inland water transport by rivers and canals is not suitable for small traders, as it takes normally a longer time to carry goods from one place to another through this form of transport."

c. Railroad.

RC Agarwal (2015) states that,

"Advantages of Railroads:

1. Dependable:

The greatest advantage of the railway transport is that it is the most dependable mode of transport as it is the least affected by weather conditions such as rains, fog etc. compared to other modes of transport.

2. Better Organized:

The rail transport is better organized than any other form of transport. It has fixed routes and schedules. Its service is more certain, uniform and regular as compared to other modes of transport.

3. High Speed over Long Distances:

Its speed over long distances is more than any other mode of transport, except airways. Thus, it is the best choice for long distance traffic.

4. Suitable for Bulky and Heavy Goods:

Railway transport is economical, quicker and best suited for carrying heavy and bulky goods over long distances.

5. Cheaper Transport:

It is a cheaper mode of transport as compared to other modes of transport. Most of the working expenses of railways are in the nature of fixed costs. Every increase in the railway traffic is followed by a decrease in the average cost. Rail transport is economical in the use of labour also as one driver and one guard are sufficient to carry much more load than the motor transport.

6. Safety:

Railway is the safest form of transport. The chances of accidents and breakdowns of railways are minimum as compared to other modes of transport. Moreover, the traffic can be protected from the exposure to sun, rains, snow etc.

7. Larger Capacity:

The carrying capacity of the railways is extremely large. Moreover, its capacity is elastic which can easily be increased by adding more wagons.

Disadvantages of Railroads:

1. Huge Capital Outlay:

The railway requires is large investment of capital. The cost of construction, maintenance and overhead expenses are very high as compared to other modes of transport. Moreover, the investments are specific and immobile. In case the traffic is not sufficient, the investments may mean wastage of huge resources.

2. Lack of Flexibility:

Another disadvantage of railway transport is its inflexibility. Its routes and timings cannot be adjusted to individual requirements.

3. Lack of Door to Door Service:

Rail transport cannot provide door to door service as it is tied to a particular track. Intermediate loading or unloading involves greater cost, more wear and tear and wastage of time.

The time and cost of terminal operations are a great disadvantage of rail transport.

5. Unsuitable for Short Distance and Small Loads:

Railway transport is unsuitable and uneconomical for short distance and small traffic of goods.

6. No Rural Service:

Because of huge capital requirements and traffic, railways cannot be operated economically in rural areas. Thus, large rural areas have no railway service even today. This causes much inconvenience to the people living in rural areas.

SECTION 3 TRANSPORTATION INFRASTRUCTURE CONDITION AND CAPACITY

3.1 Introduction.

Infrastructure in Pennsylvania	Grade Summaries
Bridges	D+
Freight Rail	D
Hazardous Waste	B-
Storm water	B+
Dams	C-
Levees	C-
Park and Recreation	B-
Transit	D
Drinking Water	D
Schools	C-
Ports	C+
Wastewater	D-
Energy	C

Inland Waterways	**D+**
Solid Waste	**C+**
Roads	**D-**

From Angel, it is found that,

Ø 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 to handle the loads and keep us moving.

Ø Every year, Pennsylvania Sections of the American Society of Civil Engineers (ASCE) provide a Report Card on Pennsylvania's Infrastructure so that each citizen and decision maker can understand how Pennsylvania's infrastructure is doing.

Ø The Report Card provides three recommendations to move Pennsylvania forward:

1. Keep up the momentum for better infrastructure: In 2013, Pennsylvania's officials showed leadership by passing a transportation package that will start putting roads, bridges, and transit back into working order. Just like senior members of the work force planning for retirement, there needs to be a plan for aging infrastructure.

2. Affirm public safety as government's #1 job: Whether it's repairs to bridges or keeping up on dam safety inspections, public safety must always be the first priority as our leaders budget and plan for the future. Ensuring that our infrastructure is resilient and online 99% of the time will keep our communities safe and our economy thriving.

3. Stop wasting money by waiting: Of the 7 infrastructure categories with D grades, all deal with transportation and water systems, and much of the repairs and long-term funding are being short-changed. Waiting will only lead to larger issues that will disrupt

our lives and cost even more when the bill comes due. We must look at the full cost of our decisions and put our savings to use.

3.2 Pennsylvania Roads and Bridges.

From Angel, it is found that,

Bridges:

1. Bridges: 5218 of the 22660 bridges are structurally efficient.

2. Inland Waterways: 260 miles of inland waterways, hence ranking it 28th nationally.

3. Out of 22660 bridges, 23% are considered structurally deficient. In average, more than 16 million vehicles cross the Commonwealth's SD bridges every day.

4. There is an improvement on the SD bridges due to investment and attention of PennDOT.

5. To reach national average of SD bridges, PennDOT has to reduce number of SD bridges to approximately 2300 which means that 400 bridges have to be taken out from the SD bridges list each year. As 300 bridges will be added every year in the list, this must be hard for PennDOT to reduce the number of SD bridges.

6. Commonwealth serves as a key link in the nation's infrastructure in the Mid-Atlantic Region, which results in disproportionately high truckloads. Both in terms of the weight of the truck and percentage of trucks in the traffic, PennDOT reveals that 15% traversing the bridges were overweight which will lead to faster deterioration of large population of bridges.

7. Mostly, bridges were designed for 50-year lifespan.

8. Age of highway bridges ≈ 54 years

9. Age of SD bridges ≈ 75 years

10. SD bridges can lead to weight restrictions, or "bridge postings", particularly if the bridge is deemed to be incapable of carrying legal truck loads. These weight restrictions contribute to traffic disruptions, such as detours and traffic congestion, and pose inconveniences for commercial vehicles and school buses which may be forced to take lengthy detours.

11. When Pennsylvania's bridges are posted, the economy of the region is directly impacted since lengthier transportation routes cost both drivers and businesses more. In addition to load capacity issues, the high percentage of functionally obsolete bridges in the Commonwealth indicates that the capacity for traffic (bridge width) or under-clearance of many bridges in the state is inadequate. The only practical way to solve this problem is through bridge replacement or major rehabilitation.

Roads

1. The 79,000 miles of roadway in Pennsylvania owned by local governments and other non-state entities are not rated by PennDOT for condition, but it is reasonable to assume they would be in equal or worse condition.

2. Additional 18,000 miles of non-state owned roadway would also be rated as Poor for a total of 27,500 miles of poor roadway.

3. Pennsylvania has as many roadway miles as any state that experiences severe winters. Pavements are susceptible to cracking and expanding due to the temperature and weather changes (freeze/thaw cycles).

4. Also, the chemicals used during snowy/icy conditions, while critical for safe travel, contribute to the decreased life of a pavement. One key to a successful roadway infrastructure program is to have sufficient funds to support roadway construction, maintenance, rehabilitation and emergency situations.

5. PennDOT has shifted its focus to bridge replacement and rehabilitation. This shift has taken funding away from roadway maintenance and its "Maintenance First" philosophy, drastically cutting the construction of new roadway miles to nearly nothing. The financial limitations have created a challenge to providing accessibility for roadway users while maintaining roadway structural integrity and safety

3.3 Pennsylvania Inland Water Ways.

From Angel, it is found that,

1. In 2012, approximately 35 million tons of commercial tonnage was transported.

2. Besides the tonnage, the frequency of locks are used in a given year to show capacity of the locks.

3. Recreational Lockage is approximately 12000 per year

4. Commercial Lockage is approximately 37000 annually.

Condition	Number of navigation dams
Satisfactory	0
Fair	7

Poor	7
Unsatisfactory	3

Condition	Number of locks
Satisfactory	3
Fair	4
Poor	4
Unsatisfactory	6

5. Condition of the locks is reflected in measures of efficiency in processing vessels and tonnage.

6. Condition of the infrastructure can be measured in terms of number of closures that occur each year. Since 2010, PA report card, they have been no instances of complete failure of major navigational facility components.

7. The condition of the locks is reflected in measures of their efficiency in processing vessels and tonnage. The locks on the Ohio River and the first lock on the Monongahela River are the largest in the Port of Pittsburgh, and thus can process more tonnage per lockage than the smaller up-river locks.

8. One measure of capacity and efficiency is the average tonnage per lockage over time.

9. The condition of the infrastructure is also measurable in terms of the number of closures that occur each year. Since the 2010 PA Report Card, there have been no instances of complete failure of major navigation facility components.

From Port of Pittsburgh Commission, it is found that,

1. Landside Corridor Served: Interstate-70

2. Corridor Description:

The M-70 Corridor includes the Ohio, Mississippi, and Missouri Rivers, and connecting commercial navigation channels, ports, and harbors, from Pittsburgh to Kansas City. It spans Pennsylvania, Ohio, West Virginia, Kentucky, Indiana, Illinois, and Missouri, connecting to the M-55 Corridor at St. Louis, MO.

3. Attributes:

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.

From Angel, it is found that,

1. 5145 route-miles of freight railroads operated, 65 freight railroads.

2. Types :

    a. 4 class I Railroads

    b. 2 class I Railroads

    c. 32 class III Railroads

    d. 27 local switching and terminal railroads

3. Commodities coming into and out by rail are dominated by coal and intermodal freight. Coal is 69% of total tons originating in Pennsylvania and 35% of terminating cons.

4. Indicators of the health of the Commonwealth's existing rail freight infrastructure are as follows:

· Physical infrastructure and bridge needs: Approximately 60 percent of the short line and regional railroad physical infrastructure is in need of extensive rehabilitation, including 170 bridges. Bridge repairs are anticipated to be greater than $ 1 million apiece.

· Choke points: There are some forty-five rail traffic choke points throughout the state. Most notable of locations needing capacity improvements include Norfolk Southern's Port Perry Branch and its Lemoyne Connector (linking NS's Lurgan Branch with its Port Road / Enola Branch at Lemoyne on the west bank of the Susquehanna River near Harrisburg).

· Ability to handle heavy loads: Excluding the Bessemer & Lake Erie (CN) and Delaware & Hudson Railroads (CP Rail), each of which has heavy load infrastructures, the short line and regional railroads are capable of handling the heavier 286,000 (286K) pound loads on only 70 percent of their infrastructure. In contrast, almost all new freight rail cars being manufactured today, outside of cars being manufactured for use in the transport of Powder River Basin (Wyoming) coal, many of which are the latest generation 315,000 pound capacity rail cars, are 286K capable.

· Derailments: Over the period from 2001 to 2005, there was an annual average of 80.4 derailments in Pennsylvania. In 2005, total derailments in the state were down 30.3 percent over the previous year (2004). It is estimated that more than 540,000 carloads of hazardous materials cross Pennsylvania's rail system each year

SECTION 4 STANDARD CAPACITY FOR ALTERNATE TRANSPORTATION MODES

4.1 Cargo Capacity.

See Figure 4.1, 4.2, 4.3, 4.4, and 4.5

Three modern transportation modes for delivering freight include by truck, by train, and by barge. The range of cargo capacity is quite large in comparison to each other. The average truck trailer can move about twenty-six tons per unit and is maxed out at forty tons. The train car is a little more versatile in the fact there are multiple types of cars to move different amounts, and types, of freight. A boxcar can move approximately 107.5 tons whereas a bulk type car can move a little more, reaching about 116.5 tons per car. Finally, a barge, usually multiple tied together and pulled at once, can move 1,500 tons per unit. The most common combination of barges is fifteen. That would be moving 22,500 tons for the fifteen barge tow. This fifteen ton barge, and even the barge as a singular piece, can move the most amount of cargo per one vehicle.

Trucks: 26 tons
Boxcar: 107.5 tons
Bulk Type: 116.5 tons
Barge: 1,500 tons
15-Barge Tow: 22,500 tons

4.2 Equivalent Units.

See Figure 4.6

Using one barge as the base unit, it would be made of 13.4 train cars or fifty-eight trucks. Expanding to one fifteen barge tow, the equivalent would be 200 train cars or 870 trucks.

1 Barge= 13.4 Train Cars=58 Trucks
1 15-Barge Tow= 200 Train Cars= 870 Trucks

4.3 Equivalent Lengths.

See Figure 4.6

One fifteen tow barge span a quarter of a mile in length. This is vastly surpassed by two one hundred car trains, taking up nearly two and a half miles in total, which carries the same amount of freight. However, the truck trailers have the longest span per amount of freight measuring eleven and a half miles bumper-to-bumper. Looking only at length, the barge would be the best, only spanning a quarter of a mile.

15-tow barge: 0.25 miles
Trains (2x100 cars): 2.4 miles
Trucks (870 bumper-to-bumper): 11.5 miles

SECTION 5 TRANSPORTATION COSTS AND CONCEPT OF OPERATIONS (ConOps)

5.1 Trucks. The average large semi truck costs approximately $140,000 and can transport 40 tons. To accomplish the mission of transporting 165,000 tons per day, 4125 trucks would be needed. It would cost $578,000,000 to purchase this number of semis. The average cost per ton-mile of 70 truck trailers is $26.61.

5.2 Barges. In general, barges costs $225,000 and can transport 1500 tons. 110 barges would be needed, which would cost $24,750,000. The average cost per ton-mile of 1 barge is 72 cents.

5.3 Railroad. A tier 3 train costs 3 million and 20 would be needed for the mission. Therefore, $60 million would need to be spent on the fleet. The average cost per ton-mile of 16 rail cars is $2.24.

5.4 Most Economical Transportation Solution. The most economic solution in general is to invest in barge transportation, both for the initial investment and for the costs per ton-mile. However, since there already is a fleet of trains, the final cost would be $32 million. Considering other factors, including the fact that barges are slower than rail and that barges cannot operate during the winter, trains are the best solution despite costing more than barges. Trucks cost so much more than each of the other types that they are not reasonable.

5.5 Concept of Operations (ConOps)

a. General Description. Our plan is to operate exclusively with trains because of their economic efficiency, ability to operate 365 days a year, and the speed at which they can transport freight. There are multiple rail systems that pass through Pittsburgh, including the Norfolk Southern and a CSX line. There are current projects that will allow for an increased density of train usage in Pittsburgh such as the J&L Tunnel. The Tunnel will allow for greater vertical clearances for the CSX Line, and this will ultimately decrease traffic in Pittsburgh significantly.

b. Operational Policies and Constraints.
http://www.railway-technical.com/tr-ops.shtml#Crews

The operating staff of a train consists of a conductor, driver, hogger, and fireman. The workers will typically work 8-hour days, but sometimes work up to 12 hours. Since trains typically run 18-24 hours a day, there are typically several shifts. At all times, 10-25% of the staff must be kept on duty.

Space constraints are apparent for dead ends or one-way railways. At these dead ends, there is often a side docking track or a place for the trains to stop then turn around for a return trip. This space constraint poses an equipment constraint, because in these situations there must be a locomotive on both the front and back of the trian. To avoid this equipment constraint, there are often loops in the track for trains to make U-turns.

c. Performance characteristics. To make sure that the capacity of the rail line is reasonable, a computer-based analysis is necessary. A program such as Viriato determines the saturation on a specific rail line, and when used in combination with other programs can accurately predict whether a line can support more trains. In order to keep trains at a safe distance from each other, signaling is used. This method involves keeping certain blocks of the railroad open, and tracking which blocks have which trains on them at certain times. According to the U.S. Department of Transportation, in 2007 the average line-haul speed was 22.5 mph. Rail is known as a safe and reliable form of transportation, and has many regulations in place to keep it this way.

d. Operational Impacts. Rail freight can have a large impact on the local population of an area if that area is densely populated. If the railroad takes up a significant amount of space, it can begin to interfere with people's lives and possibly even force them to move. However, Pittsburgh is a city that is highly accustomed to a large amount of freight, and the plan is not to add new trains. Instead, the fleet is being renovated, so there should be a minimal impact to the size of the railways. Considering that any form of freight transportation pollutes the environment, there are definite impacts from it. Rails emit VOC, NOx, carbon dioxide, and other pollutants that can cause cancer after a significant amount of time. Thankfully, the goal of the design is to optimize efficiency and add after-treatment to the trains to make them follow tier 4 standards, which is much better for the environment.

e. Continuity of Operations. Continuity of operations during different emergency situations such as a natural disaster or an attack is extremely important considering that vital freight will be transported. Maintaining proper communication between trains is critical, as in the case of an emergency, the exact location of the incident can be known. If an accident happens, knowing where all vehicles are will help prevent environmental damage that can result from hazardous materials. In dire circumstances, FEMA can be contacted for assistance.

SECTION 6 EPA DIESEL EMISSION STANDARDS

6.1 Background. http://www3.epa.gov/otaq/locomotives.htm
dieselnet.com/standards/us/nonroad.php

In 1994, off-road diesel engines were adopted for engines over 50hp. These engines had tier 1-3 standards. In 1998, tier 2-3 standards were introduced for equipment under 50hp. From 2000 to 2008, tier 2-3 standards were more stringent for all vehicles.

Tier 1-3 standards have little or no gas after-treatment, but tier 4 standards require a gas after-treatment. Tier 4 emission standards were finalized on May 11, 2004, and they have been implemented since 2008.

6.2 Tier 0-2 Standards.
dieselnet.com/standards/us/loco.php

For tiers 0-2, locomotives are not required to have an exhaust gas after-treatment. For tiers 1-3, sulfur content is not regulated in diesel fuels.

Tier 0 started in 2000 and applies to locomotives manufactured between 1973 and 2001. Tier 1 applies to locomotives manufactured between 2002 and 2004. Tier 2 applies to locomotives manufactured in 2005 or later (Figure 6.1).

6.3 Tier 3-4 Standards.

Tier 3 is met using engine technology, but tier 4 is met with an exhaust after-treatment. There are several kinds of gas after-treatment, such as particulate filters for particulate matter control and urea-SCR for NOx control. However, these tiers do not apply to historic locomotives or passenger-carrying railcars (Figure 6.2).
(note:bhp-br=brake horsepower hour)

Switch locomotives are smaller with about 1200 -3000hp, but line haul locomotives are larger with about 3000-4000hp. All locomotive engines should last for at least 10 years. Locomotives manufactured before 2000 should last at least 750, 000 mi.

SECTION 7 DIESEL ENGINE EXHAUST EMISSIONS (DEEE)

7.1 Diesel Emission Chemistry.

a. NOx. www3.epa.gov-NOx

There are several reactions that can produce NOx, including $CH+N_2$ during combustion, NH_2+NO from fossil fuels, and also HCCO+NO.

There are several forms of NOx. NxOx dissolves in H_2O to form HNO_3 or HNO_2. N_2O depletes ozone with a half-life of 100 to 150 years. NO is the most common product, but poses no real threat to animals because it is not very soluble in H_2O. NO is rapidly converted to NO_2 and lesser amounts of N_2O. N_2O is not very reactive. 50% of NOx comes from transportation equipment.

b. Particulate Matter (PM). www3.epa.gov/pm/

PM consists of very small particles and liquid droplets. It can also include metals, organic chemicals, soil or dust particles, and acids formed from nitrates and sulfates.

Particles that are 10 micrometers in diameter or smaller pose the most health hazards. Within this range, there are inhalable coarse particles, which are between 2.5 and 10 micrometers in diameter. There are also fine particles, which are 2.5 micrometers in diameter or smaller.

c. CO_2. www3.epa.gov/climatechange/ghgemissions/gases/co2.html

CO_2 accounts for 82% of greenhouse emissions by people. In the U.S., 31% of CO_2 emissions are from transportation equipment. CO_2 is not easily destroyed and can almost exclusively be absorbed by trees, plants, and other organic materials.

d. Hydrocarbons (HC). http://www.eolss.net/sample-chapters/c08/e6-193.pdf

Hydrocarbons form from the combustion of C-containing organic compounds in the atmosphere, which consists mostly of N_2 and O_2 with some H_2. The most common hydrocarbon is CH_4, but there are more harmful ones.

Hydrocarbons can also react with O_2 to produce H_2O vapor and CO_2.

7.2 Diesel Emission Reduction Strategies. http://www.dieselforum.org/about-clean-diesel/what-is-scr

SCR (Selective Catalytic Reduction): a liquid-reductant agent is injected through a catalyst into the exhaust of a diesel engine. The reductant is sometimes ammonia, but is usually automotive-grade urea, also known as diesel exhaust fluid (DEF). DEF converts NOx into nitrogen gas, water vapor, and small amounts of carbon dioxide. SCR can reduce diesel emissions by up to 90%.

http://www.cdti.com/content/americas/products/hd_diesel_products.htm

DOC (Diesel Oxidation Catalyst) breaks down components of diesel emissions to form less harmful products. DOC reduces PM by up to 40%.

DPF (Diesel Particulate Filter): Most DPFs are EPA-approved and can reduce PM by up to 90%.

EGR (Exhaust Gas Recirculation) reduces NOx when the engine starts and recirculates part of the exhaust. EGR and SCR are often implemented together as in our proposal.

CCV (Closed Crankcase Ventilation Systems): eliminates 100% of crankcase emissions. Crankcase emissions consist of water, acids, unburned fuel, oil fumes, and particulates.

7.3 Alternate Fuels. http://www.truckinginfo.com/article/story/2012/01/what-alternatives-are-there-to-diesel.aspx

Natural gas is the most realistic alternative to diesel fuels that is economically and environmentally beneficial. The most eco-friendly option, although not the most economically-efficient one, is biofuels. Some possible biofuel options are DME (dimethyl ether) and algae-based biofuel. Algae can grow and produce oil indefinitely, making it a sustainable source of biofuel.

The only other realistic option for alternative fuels is hydrogen fuel cells, although it would be expensive; there not many hydrogen refuelling stations, and many new engines would have to be implemented to accommodate the wide range of diesel engines.

7.4 Human Health Issues. http://oehha.ca.gov/public_info/facts/dieselfacts.html

Diesel exhaust contains several small particles that can be lodged deeply in the lungs and can even be carcinogenic. Common carcinogens in diesel exhaust include arsenic, benzene, formaldehyde, and nickel. According to the OEHHA (Office of Environmental Health Hazard Assessment), long-term exposure to exhaust from diesel engines poses the most health hazards out of all air pollutants. According to the ARB (Air Resources Board), 70% of the cancer risk the average Californian experiences from breathing toxic air is from diesel emissions.

OEHHA analyzed more than 30 studies of people who worked around diesel engines or equipment. ARB used the results of this assessment to estimate that the level of airborne diesel-particles in California during 2000 was high enough to cause an excess of 540 cases of lung cancer per million people that would not have occurred without diesel emissions.

Lung tissue is susceptible to damage from diesel emissions, especially if people have asthma, emphysema or chronic lung or heart disease. NOx lowers the body's resistance to respiratory infection and reacts with other pollutants in the atmosphere to form smog.

SECTION 8 LOCOMOTIVE FLEET UPGRADE

8.1 Alternatives.

Five main options seemed to the feasible with the given information.

Option 1: No upgrades

Option 2: Upgrade entire fleet to Tier 3 (via new trains, upgrades, and after-market systems)

Option 3: Upgrade entire fleet to Tier 4 (via new trains, upgrades, and after-market systems)

Option 4: Mix of Tier 3 and Tier 4

Option 5: Use alternate fuel

Option 1 was quickly eliminated because it had zero impact environmentally even though it was the cheapest.

Option 2 is a fairly strong choice at the start because Tier 3 is a nice middle point between the expensive Tier 4 and the environmentally inferior Tier 2.

Option 3 is the most expensive but also supplies the most reduction in NOx.

Option 4 is also another interesting option because it is cheaper than Option 3 but gives off fewer emissions compared to Option 3.

Option 5 provides the most radical change. It would require fueling stations as well as upgrades to the locomotive itself.

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.

See Figure 8.1 and Figure 8.2

8.4 Upgrade Strategy.

The way the upgrades worked, it was found that there was a reasonably cheaper way to get a Tier 2 locomotive to a Tier 4 locomotive. Because there was no cost for a Tier 3 to a Tier 4 upgrade, it was best concluded that the upgrade would cost $250,000.

Due to the existing mileage on twenty of the existing locomotives, ten locomotives would be sold replaced by all new Tier 3 locomotives and subsequently add after-market systems. The other ten will be sold and not replaced. They are unnecessary as we still have more than enough locomotives to run move the freight required. This upgrade to ten locomotives (Group A) will bring the emissions down to Tier 4 level on the ten locomotives in the fleet. The locomotives will sell for one and a half million dollars each, totaling thirty million dollars including all twenty locomotives, and will cost thirty two and a half million to upgrade and replace Group A. The total cost for this potion would be seventeen and a half million dollars.

The remaining thirty locomotives (Group B) all have minimal mileage, only a maximum of 450,000 out of 750,000, and would fare better by upgrading these existing Tier 2 to Tier 3 standards. Once up to a Tier 3, an after-market system would then be applied, much like the twenty other locomotives, to make the emission that of a Tier 4. The cost of this upgrade from Tier 2 to Tier 4 would only be thirty million for all thirty locomotives. This is due to the after-market addition to the Tier 3s.

The option of moving to an alternate fuel was swiftly moved off the table once the startup cost was realized. The cost of a fueling station is one billion dollars. That is the equivalent of 250 new Tier 4 locomotives. The cost of the fueling stations was the primary reason alternate fuel sources are not utilized.

8.5 Upgrade Schedule and Costs.

For the locomotives in Group B, upgrading should take place all at once per locomotive. That is, each locomotive should go from a Tier 2, go through all upgrading necessary for a Tier 4, and then be send on its way. For the cost that it takes to make a Tier 3 a Tier 4, at no point should any Tier 3 locomotives be running. The upgrade schedule will be over three years. For 2016, the entirety of Group A and the ten locomotives from Group B that have the most mileage should receive their respective upgrades. Half of the remaining twenty locomotives left to be upgraded in Group B would upgrade in 2017. The same should be done in 2018 to complete all necessary improvements for the fleet.

SECTION 9 SUMMARY

The proposal for GE Transportation is to upgrade all locomotives to meet tier 4 emission standards and to reduce the fleet size to 40 locomotives with a return on investment of two years. The proposal is to help reduce NOx, PM, CO_2, and hydrocarbon emissions with SCR and EPG to meet tier 4 standards and to better protect human and environmental health.

(SECTION 2) Pittsburgh transports a majority of its freight by rail. This has led to a number of issues, such as smog. Not only is the smog an issue, but the age of the trains are reaching inhibitive levels. The city would benefit by an increase in freight capacity, which is being considered. Hence, the objective of this project is to plan the most efficient method to move 165,000 tons of freight in and out of Pittsburgh via rail, truck, or barges. EPA standards are a major consideration as well as cost. The advantages and disadvantages of trucks, barges and railroads are taken into consideration in choosing the best method to meet the requirement set by EPA.

(SECTION 3) The section provides summary of infrastructure condition and capacity of roads, bridges, inland waterways, and freight rail system. There are pro and cons for these

three transportation infrastructure. Based on 2014 Report Card for Pennsylvania Infrastructure, the average grade given to these three is D, which is considered as poor. In order to move Pennsylvania forward, three recommendations have been suggested; 1. Keep up the momentum for better infrastructure. 2. Affirm public safety as government's first job. 3. Stop wasting money by waiting.

(SECTION 4)Of the three modes of transportation, the barge was able to carry the most while taking up the least amount of mileage. Next was the boxcar and bulk type train car for both categories. Having the longest stretch while carrying the least amount per vehicle, the truck trailer was last in all areas concerning cargo capacity and length per ton.

(Section 5) By cross-comparing available costs about both the purchase price and the costs per ton-mile, a reasonable economic solution can be decided upon. Truck transportation clearly is not realistic, and is vastly more expensive than the other two types. Barges did come out to be the most cost effective option of the three. However, trains were not far behind. Trains are also a much faster form of transportation and can operate in all but the most extreme of weather circumstances. Because of this, trains are the best option available for GE and should be used over the other modes of transportation. Also, since we do not need to purchase new trains but simply upgrade the existing fleet, no new infrastructure needs to be built. Trains are known as a safe and regulated means of transportation, and they will not add any significant negative effects to the people of Pittsburgh or the environment of the city. In case of an emergency, effective communication between all levels of the company will ensure continuity of operations. In dire circumstances, FEMA can be called.

(Section 8) There were five options that seemed possible when upgrading the fleet of trains. Ultimately, option number 3, upgrading the entire fleet to Tier 4, was chosen. The upgrades would take place over a three year period and would begin with ten Tier 2 locomotives under 450,000 miles being upgraded to Tier 3s and given after-market systems while ten locomotives over 450,000 miles are sold and replaced by Tier 3 locomotives with after-market systems. The next two year will see ten locomotives each under 450,000 miles receiving the same treatment as the identical locomotives the year before. The remaining ten locomotives that are over 450,000 will be sold and not replaced.

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Figures

Figure 2.6(a). Typical Diesel Truck and Trailer.

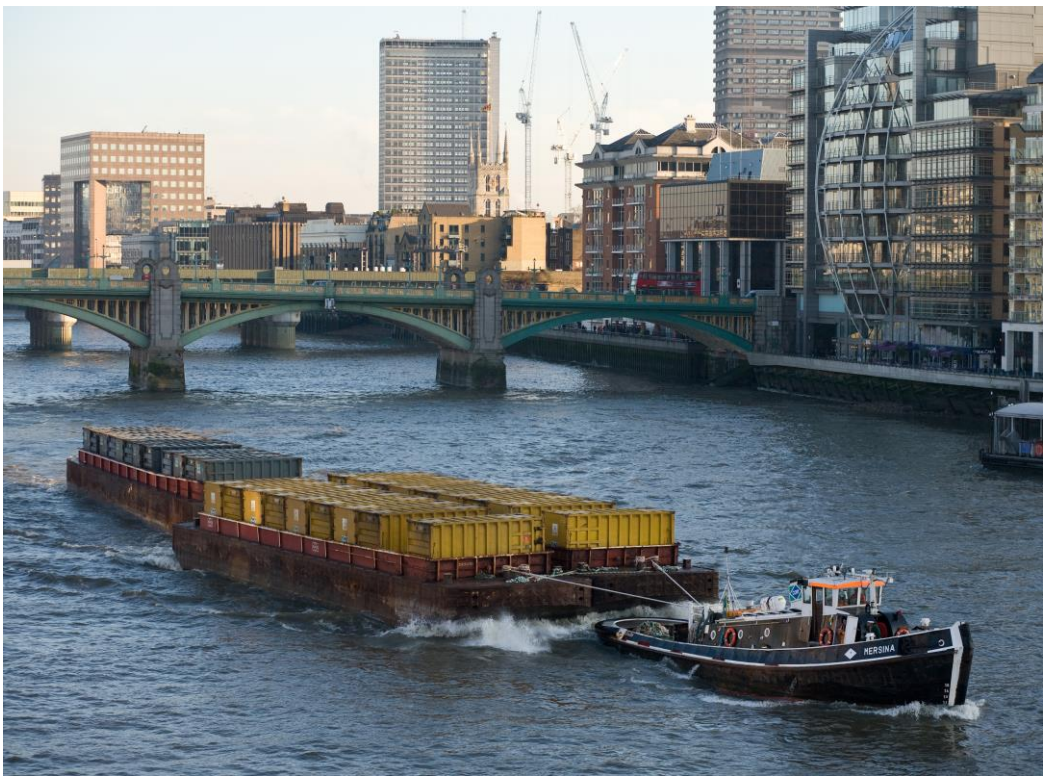


Figure 2.6b(i). Barge

Figure 2.6b(ii). Towboat

Figure 2.6c(i). Hopper

Figure 2.6c(ii) Refrigerator car

Figure 2.6c(iii) Passenger Car

Figure 2.6c(iv) Intermodal Car

Figure 2.6c(v) Tank Car

Figure 2.6c(vii) Flat Car

Figure 3.2(i) Benjamin Franklin Bridge

Figure 3.2(ii) Knight Road interchange in Northeast Philadelphia

Figure 3.3(i) America's Marine Highway Corridor

Figure 3.3(ii) Monongahela River

Figure 3.4(i) Pennsylvania Northeast Railroad

Lake Superior
Lake Michigan
Lake Huron
Lake Erie
Lake Ontario
Car Ferry Service
St. Ignace
Mackinaw City
Harbor Springs
Petoskey
Mancelona
Traverse City
Cadillac
Falmouth
Big Rapids
Grand Rapids
Kalamazoo
Milwaukee
Chicago
Hammond
South Bend
Plymouth
Fort Wayne
La Crosse
Effner
Peoria
Decatur
Terre Haute
Effingham
Vandalia
Greenville
St. Louis
Vincennes
Indianapolis
Logansport
Frankfort
Gosport
Columbus
Madison
New Albany
Louisville
Cincinnati
Morrow
Middletown
Richmond
Dayton
Springfield
Ridgeville
Bradford
Lima
Bucyrus
Detroit
Toledo
Sandusky
Gibsonburg
Cleveland
Marcy
Akron
Youngstown
Orrville
Canton
Ashtabula
Port Burwell
Buffalo
Dunkirk
Rochester
Sodus Point
Nunda
Himrod
Elmira
Troy
Olean
Bradford
West Lima
Oil City
Warren
Corry
Titusville
Meadville
Franklin
Sharon
Butler
Pittsburgh
Mt. Pleasant
Connellsville
Uniontown
Greensburg
Johnstown
Altoona
Tyrone
Bellefonte
Lewisburg
Williamsport
Sunbury
Bethlehem
Hazelton
Scranton
Stroudsburg
Wilkes-Barre
Shamokin
Harrisburg
Mechanicsburg
Carlisle
Chambersburg
Hagerstown
Martinsburg
Winchester
Washington, D.C.
Baltimore
Lancaster
Reading
Philadelphia
Camden
Trenton
Princeton
Rahway
Elizabeth
Newark
New York
Jersey City
Bay Head
Toms River
Atlantic City
Ocean City
Barnegat
Wildwood
Cape May
Rehoboth Beach
Dover
Denton
Salisbury
Berlin
Franklin City
Cape Charles
Kiptopeke
Fort Monroe (Old Point Comfort)
Little Creek
Virginia Beach
Portsmouth
Norfolk
Pocomoke
Cambridge
Oxford
Easton
Chestertown
Pocomoke
Pepes Creek
Cheriton
Cape Charles
Fairmont
Morgantown
Connellsville
Uniontown
Greensburg
Mt. Pleasant

Figure 2.4(iii) Freight Rail GE C30ACi in Pennsylvania

Section 4

Figure 4.1-Truck Trailer

Truck: 26 tons

Figure 4.2-Boxcar

Boxcar: 107.5 tons

Figure 4.3-Bulk Type Car

Bulk Type: 116.5 tons

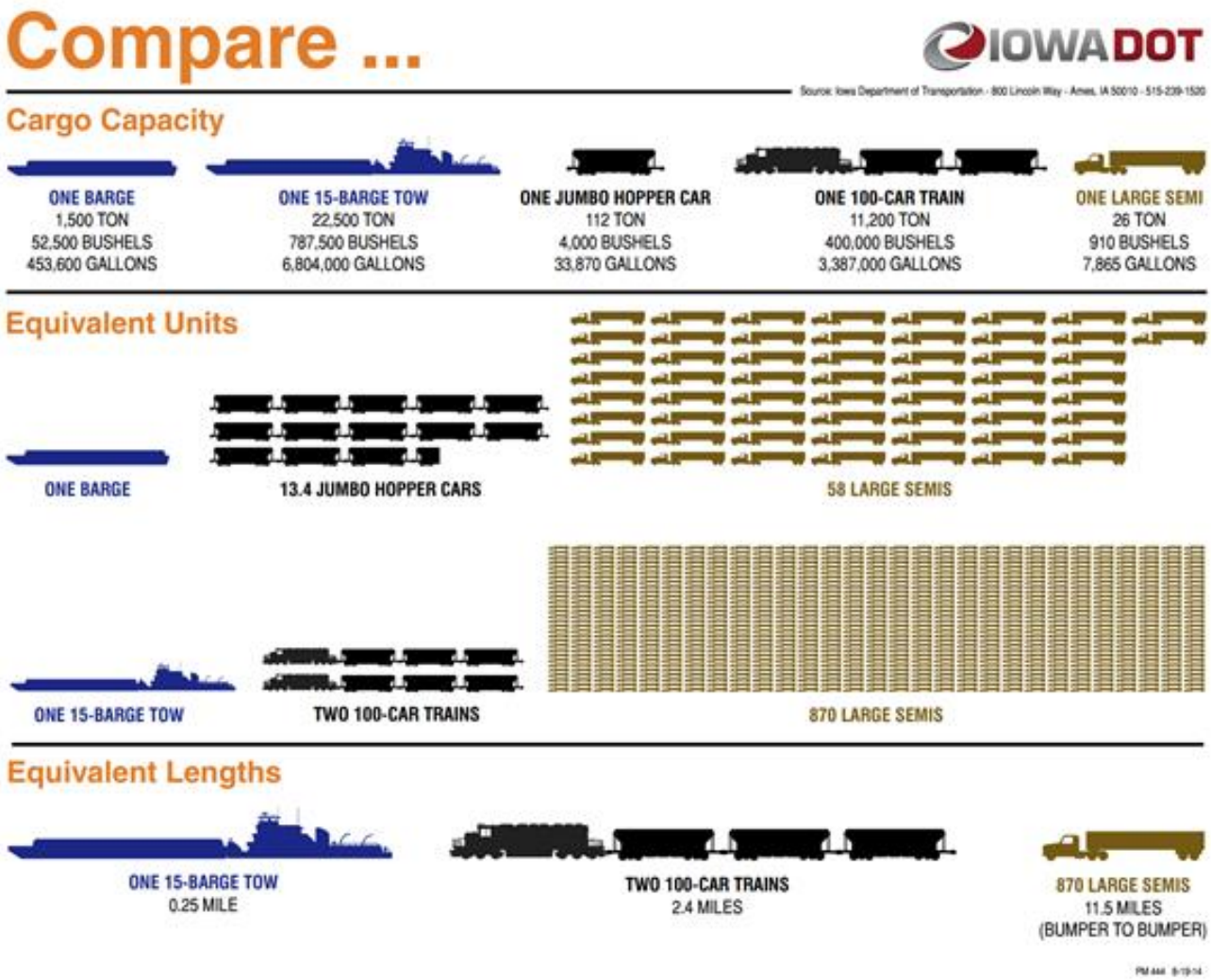
FIgure 4.4-Barge

Barge: 1500 tons

Figure 4.5-15-Tow Barge

15-Barge Tow: 22,500 tons

Figure 4.6-Unit Comparison and Length



Section 6

Figure 6.1-Tier 0-2 Locomotive Emission 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

Figure 6.2-Tier 0-4 Locomotive Emission Standards

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.

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.

Figure 2. Typical Diesel-Electric locomotive.

Figure 3. Typical Inland Water Ways Barge and Tug.

Section 8

Figure 8.1-Upgrade Costs

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

Note: $$ are completely fictional for this assignment

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Figure 8.2-Total Costs and Upgrades

No. of Existing Locomotives	Locomotive Group Designation	Assumed Existing Locomotive Mileage Range	Assumed Existing Diesel Type	Upgrade/Replacement	New/Upgrade Train (Millions of dollars)	After-market System (Millions of dollars)	Selling Price (Millions of Dollars)	Tier of Train
10	A	<150,000	Tier 2	UPGRADE Tier 3 + After market	-7.5	-2.5	0	Tier 4
10	B	>150,000 and <300,000	Tier 2	UPGRADE Tier 3 + After market	-7.5	-2.5	0	Tier 4
10	C	>300,000 and <450,000	Tier 2	UPGRADE Tier 3 + After market	-7.5	-2.5	0	Tier 4
10	D	>450,000 and < 600,000	Tier 2	NEW Tier 3 + After market	-30	-2.5	15	Tier 4
10	E	>600,000 and <750,000	Tier 2	NEW Tier 3 + After market	0	0	15	Tier 4
					-52.5	-10	30	
							-32.5	