

ABSTRACT

KEILSON, DAVID PAUL. U.S. International Container Trade: Trends, Air Quality Effects, and Best Practices for Mitigation. (Under the direction of Dr. Billy M. Williams.)

The purpose of the paper is to identify relationships between international trade and air quality, and to identify principles and practices to mitigate the air quality impacts of trade growth. The focus is on container trade. The primary modes examined are trucking, rail, and marine. After a brief background on the magnitude of U.S. international container trade, the paper identifies trends in international and domestic container transportation. Freight contributions to national and regional emissions are described. Air quality at major gateways and hubs is examined. Current and proposed emission and fuel standards are discussed and compared across modes. Projections of future freight emissions and modal contributions are discussed. Principles are described to guide the evaluation of mitigation practices. A list of practices is compiled for each mode, including technology, operational, institutional, and infrastructure approaches. Recommendations are given for mitigation strategies and for further research.

U.S. International Container Trade: Trends, Air Quality Effects, and Best Practices for Mitigation

by
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A thesis submitted to the Graduate Faculty of
North Carolina State University
in partial fulfillment of the
requirements for the Degree of
Master of Science

Civil Engineering

Raleigh, North Carolina

2009

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BIOGRAPHY

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ACKNOWLEDGEMENTS

I wish to thank my committee members, Dr. Williams, Dr. List, and Dr. Stone, for their assistance, counsel, and patience as I have worked on this project. I also wish to thank Erik Stromberg, the consultant who has worked with Dr. Williams, Dr. List, and me on the project for US DOT. Having little previous background in goods movement or air quality, I needed and sought much advice. And, I owe a special thanks to Dr. Williams for persuading me at the outset to accept this project and topic. Although I found it quite challenging, I am very grateful for the opportunity to work on such an interesting and unique topic. I also thank the other faculty who helped me work towards my master's degree: Dr. Hummer, Dr. Rodriguez (UNC), and Dr. Kemahlioglu (UNC). Finally, I want to thank the authors of the many outstanding reports, articles, books, and presentations upon which my work was built.

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LIST OF ABBREVIATIONS

AMP	Alternate Maritime Power (“Cold-Ironing”)
APU	Auxiliary Power Unit
CAGR	Compound Annual Growth Rate
CARB	California Air Resources Board
CHE	Cargo Handling Equipment
CMAQ	Congestion Mitigation Air Quality
CNG	Compressed Natural Gas
CO	Carbon Monoxide
CO ₂	Carbon Dioxide
DC	Distribution Center
DOC	Diesel Oxidation Catalyst
DPF	Diesel Particulate Filter
EBMP	Environmental Best Management Practice
EGR	Exhaust Gas Recirculation
EPA	Environmental Protection Agency
GHG	Greenhouse Gas
HAM	Humid Air Motor
HAP	Hazardous Air Pollutant
HC	Hydrocarbons
HFO	Heavy Fuel Oil – same as RFO
IMO	International Maritime Organization
LEZ	Low Emission Zone
LNG	Liquefied Natural Gas
LTL	Less Than Truckload
MARAD	Maritime Administration
MARPOL	Maritime Pollution (IMO)
MDO	Marine Distillate Oil
MGO	Marine Gas Oil
MOU	Memorandum of Understanding
NAAQS	National Ambient Air Quality Standards

NMHC	Non-Methane Hydrocarbons
NOAA	National Oceanic and Atmospheric Administration
NO ₂	Nitrogen Dioxide
NO _x	Nitrous Oxides
OCR	Optical Character Recognition
OGV	Ocean Going Vessel (Category 3 marine vessel, > 30 liters/cylinder)
PM	Particulate Matter
RFID	Radio Frequency Identification
RFO	Residual Fuel Oil
RTM	Revenue Ton Miles
SCR	Selective Catalytic Reduction
SECA	Sulfur Emission Control Area (IMO designation requiring ≤ 1.5% sulfur fuel)
SIP	State Implementation Plans
SO ₂	Sulfur Dioxide
SO _x	Sulfur Oxides
TEU	Twenty Foot Equivalent Unit (20' Container)
ULSD	Ultra Low Sulfur Diesel (15 ppm)
VMT	Vehicle Miles Traveled

0.1 EXECUTIVE SUMMARY

This thesis is based on research performed for a US Department of Transportation study concerned with the environmental effects of the rapid growth in international container trade. The primary topics are as follows: current trends in international trade, environmental effects, implications and principles for best practices in mitigation, and a comprehensive list of potential best practices. The US DOT study will include implications for policy, which is not included in this thesis. Both the thesis and the US DOT study focus on containerized goods and air quality at ports, border crossings, and freight hubs. The emissions covered include criteria pollutants, greenhouse gases, and ultrafine particulate matter. The primary focus is highway, marine, and rail, as these modes are the largest contributors to freight emissions. Air freight contributes a relatively small amount of emissions, despite strong growth in the volume of air freight.

The rapid growth of international trade must be handled in ways which reduce impacts to air quality. Failure to do so will be injurious not only to health, but also to economic development, as freight-related air quality problems hinder expansion projects needed to move freight efficiently. To address the problem effectively, there is a need to:

- Describe trends in goods movement and emissions standards;
- Understand the nature, magnitude, and location of the problem;
- Identify the practices available for reducing freight emissions;
- Provide principles to evaluate the available practices.

Trends in Goods Movement

International trade comprises a growing percentage of the US economy. It has grown from 13% in 1990 to approximately 30% in 2006. Container trade is a substantial portion of the total trade value, with 27 million TEU in ocean borne trade in 2006. Container trade has been

growing rapidly, and shows no signs of abating in the near future. Total waterborne US international container trade has been growing at roughly 7% per year, doubling every 10 years, and waterborne container imports have been growing at approximately 10% per year, doubling every 7 years. This rapid growth is not limited to Los Angeles, Long Beach, and New York, but includes a number of ports on the west, east, and gulf coasts.

In addition to the rapid growth, waterborne container trade has been concentrating at the largest ports, with the ten largest ports handling over 85% of the volume, up from just under 80% in 2000. Container trade is also concentrated at the largest border crossings, with the top ten land gateways accounting for about three-fourths of surface trade by value. Mega-warehousing, typically located near major ports, is adding to the concentration of volumes at key gateways.

Ports are struggling to expand to meet the demand, often hindered by environmental challenges which limit capacity growth, also facing challenges from community and environmental groups and air quality agencies. Railroads also face challenges for growth, including opposition based on environmental concerns, and difficulty obtaining space to expand rail yards.

Congestion sometimes occurs at ports, and is also a concern at border crossings, with truckers sometimes waiting hours to make a crossing. In addition to millions of hours of wasted time to both freight and passenger vehicles, congestion decreases velocity and reliability, sometimes requiring higher inventory, decreases the effective capacity of the transportation network, and contributes to a shortage of drivers, since congestion increases the number of drivers required to deliver the same quantity of goods. Congestion is also experienced in rail transportation, decreasing velocity and reliability, which decrease the attractiveness of this fuel-efficient and safe mode. Congestion in the rail network sometimes leads to inefficient movement, with truck moves between rail yards used to reduce delays.

Further, congestion increases fuel consumption, transportation costs, emissions and exposure to emissions. Exposure is increased due to more time on the highways, where concentration of pollutants is elevated. Also, emissions of ultrafine PM, one of the most harmful pollutants, can be higher at low engine speeds. Congestion increases exposure to emissions not only to drivers, but also to those whose homes, workplaces, or schools are near highways.

Both trucking and intermodal have experienced strong growth, particularly intermodal with growth over ten percent per year for the last several years, despite a significant decreased trackage. Class 1 rail carriers are in the midst of a major expansion, double- and triple-tracking on major corridors. NAFTA trade accounts for approximately one third of total US international trade by value, with about 90% of NAFTA trade occurring by surface modes. In recent years, most of the growth in NAFTA surface trade has been by rail. Growth in international air freight has also been strong.

Marine vessel size has grown sharply, with recent vessels delivered having a capacity over 10,000 TEU. This increase puts new demands on ports in terms of larger cranes, stronger wharfs to support the larger cranes, and higher peak demands both at the dock and on highways serving the ports. Up to the present, the largest vessels are used in trans-pacific trade, with the resulting pressures focused on west coast ports. However, use of larger vessels is increasing in transatlantic trade as Asia to East Coast traffic via Suez is growing, and the Panama Canal will be expanded to handle vessels up to 12,000 TEU. All of these are or will be placing demands on East Coast and Gulf Coast ports to accommodate larger containerhips.

In addition to the larger vessel size, other changes are occurring which add to the challenges faced by ports. One example is the consolidation and diversification which are occurring among ocean carriers. Five carriers control over 50% of the global fleet. Many of the larger carriers are incorporating terminal operations and logistics. At the same time, use of

consortia and alliances is decreasing. This results in additional pressure on port capacity, due to less ability to share infrastructure among carriers.

Environmental Implications – Air Quality

Many of the nation's largest ports and land gateways suffer from poor air quality. Six of the ten largest container ports and three of the five largest land gateways are in non-attainment for one or more criteria pollutants (NO₂, SO₂, PM, CO, ozone, and lead). Freight contributes a substantial portion of total US mobile-source NO_x, PM, and GHG emissions, with almost 50% of mobile-source NO_x emissions, 36% of mobile-source PM-10 emissions, and 25% of mobile-source GHG emissions. These percentages are a national average, and are even higher in some regions.

Among regions, air quality problems vary in pollutants, severity, sources, and dispersion based on prevalence of each freight mode, local topography and meteorological conditions. Even with the same pollutant, causes vary between regions. For example, ozone can be primarily due to NO_x, to VOC, or both. Some aspects of emissions and air quality are debated, including the dispersion of pollutants. Some claim that NO_x emissions travel a limited distance, while others state long range dispersion, and suggest that in the future a substantial percentage of ambient NO_x on the west coast will come from Asia. These disagreements about dispersion result in disagreements on which practices and policies should be pursued.

Emissions from freight are believed to contribute to numerous health problems, especially near ports and hubs. Health effects include respiratory problems in people of all ages, cardiovascular problems, and early death. This belief is supported by numerous studies, with growing public concern. Ultrafine emissions are particularly concerning, as their health effects are some of the most serious due to their small size which causes deeper deposition. Although current standards limit total PM emissions, the low mass of ultrafine PM means

that these emissions are effectively unregulated. Some countries are considering limiting ultrafine emissions by imposing a particle number limit rather than a mass limit.

Current and proposed EPA emission standards are expected to cause a large decrease in emissions from freight trucks, locomotives, and Category 1 & 2 marine vessels - all but the large ocean-going vessels. Unfortunately, ocean-going vessels are not covered by these regulations, but rather are under IMO jurisdiction, whose emission standards are far less stringent. Fuel standards and emission standards vary tremendously between modes, with fuel for ocean going vessels containing nearly 2,000 times as much sulfur as the current ULSD highway diesel fuel. Emission standards also vary between modes, with Tier 2 locomotive (2005) emitting 10 times as much PM and NO_x as 2007/2010 trucks on a grams per brake horsepower basis. Emissions from ocean going vessels are even higher, with typical NO_x emissions of approximately 20 g/kW-h NO_x compared with the latest trucks at 0.2 g/ kW-h. Even the latest ocean going vessels have high emissions compared to trucks and locomotives, at approximately 15 g/ kW-h NO_x. PM emissions from ocean going vessels are not regulated, and are high due to the high sulfur content of the fuel. Without further improvements in ocean going vessel emissions, these vessels will become a large percentage of total freight emissions in many port cities.

In terms of human health, the greatest problem of freight is primarily in cities, at border crossings, and in some coastal areas. This will increasingly be the case, due to decreases in truck and locomotive emissions, increasing congestion, and failure thus far to adequately control emissions from ocean going vessels. In rural areas, although large volumes of freight pass through, exposure to freight emissions is limited by the low population density. Health benefits per unit reduction of emissions are larger in cities and in heavily polluted areas because more people are exposed to the emissions. Also, in areas where pollution is low, health benefits of emission reductions are smaller, since health effects are believed to be minimal at low levels of exposure.

Best Practices

Although opportunities to reduce freight emissions abound, adoption is sometimes hindered by lack of awareness of practices, conflicting direction from different agencies, and policies which impose detailed requirements rather than establishing reduction targets and allowing flexibility in their achievement. Although most stakeholders are in agreement about the need to reduce emissions, each group has their own priorities. Differing priorities of stakeholder groups hinder adoption of measures to reduce freight emissions, despite widespread support of the goal.

Practices are needed which are effective in reducing emissions in the regions of concern. The practices must be economical and institutionally feasible. There are some practices with widespread application, which provide both emission and economic benefits. The most attractive practices are those with the greatest health benefits at lowest costs. This may be different than the practices yielding the greatest reduction in emissions. The report describes principles which can be used to evaluate potential best practices. The principles are derived from current trends in freight transportation and the environmental impacts of these trends.

Available practices include those based on improved engine and after-treatment technology, carrier operational strategies, institutional approaches, and improved logistics for shippers. In addition to reduced emissions, many practices offer other benefits, such as reduced costs and increased velocity, reliability, capacity, safety, and security. Over 250 current or potential practices have been identified, and are listed in the Appendix. The list of practices includes approaches for carriers, ports, and shippers. Greater emphasis was placed on carriers and ports, with practices for shippers covered more briefly.

Recommendations for Action

Based on freight transportation trends, air quality impacts of those trends, available practices and principles for their evaluation, and current and proposed emission standards, the following actions are recommended. These are applicable to state and federal transportation departments and air quality agencies.

- Develop and maintain a list of environmental best practices for each mode. Assessment should consider the location of emission reductions, since the location of reductions is as relevant to health benefits as the amount of reductions.
- Consider emissions from ocean going vessels a top priority for mitigation measures and policy action. Large reductions in marine emissions are possible, either by using lower sulfur fuel, or by individual or combinations of technologies. While some approaches increase costs, others decrease costs. Engine rebuild intervals on ocean going vessels are relatively short, which provides frequent opportunities for technology-based emission reductions.
- Support adoption of the proposed Tier 3 and Tier 4 emission standards for locomotives. Despite the environmental benefits of intermodal over trucking, reductions in locomotive emissions are needed to temper opposition to the growth of freight rail.
- Place additional focus on ultrafine PM emissions from diesel trucks. Particular attention should be paid to exposure in heavy traffic, due to increased exposure time, higher emissions of ultrafine particles at low engine loads, short-range dispersion of ultrafine particles, and lack of effective regulation.
- Promote standards to facilitate the adoption of new technologies such as RFID and alternative maritime power.

Current data and identified trends are sufficient to support a number of conclusions and recommendations as described above and in section 6 of the report. However, research is needed to develop new practices, and to achieve greater agreement on best practices and policies.

Recommendations for Further Research

To support more effective mitigation practices and policy analysis, research in the following key areas is recommended. See the recommendations at the end of the report for a more complete list.

- Investigate the effects of container concentration and port specialization on transportation infrastructure, freight efficiency, land use, air quality, and port capital requirements.
- The rapid growth and concentration of container volumes and the limited availability of land for expansion will require increased port and terminal productivity, which will require large capital expenditures. The ability to make these large investments is likely to determine the long-term growth or stagnation of individual ports. Will adequate funding be available at both publicly and privately run ports/terminals?
- Monitor trends in the trans-shipment of goods through Canada and Mexico and the effects on U.S. transportation infrastructure.
- Examine causes and effects of the decreasing modal share of inland waterborne transport, including effects on infrastructure, air quality, land use, industry, and agriculture.
- Low emission zones (LEZs) can be a cost-effective approach to reduce emission where the need is greatest. Investigation of specific approaches is recommended.

- Ultrafine particulate matter (PM) emissions, those less than 0.1 microns, are an important research topic. They are the most harmful particulate emissions, are not fully understood, and are difficult to control.
- Increase understanding of pollutant dispersion. This is vital to mitigation efforts, and will enable consistent methods to evaluate and compare mitigation measures and policies.
- The impact of CO₂ emissions from air cargo may be underestimated and should be quantified, taking into account the greater warming effect of night flights.

1.0 INTRODUCTION

Background & Motivation for Study

International container trade has grown sharply in recent years. This rapid and sustained growth puts pressure on freight gateways and hubs to handle the growing volumes, and the pressure is exacerbated by the concentration of volumes at the largest gateways. While the growth and concentration call for expansion of infrastructure, environmental concerns, particularly air quality, limit the ability to make the needed improvements as resistance is encountered from community groups, environmental groups, and air quality agencies. These concerns are based on the significant role of freight in air quality problems and the associated adverse health effects.

Emissions from heavy duty trucks, locomotives, marine vessels, and cargo handling equipment are a substantial and growing portion of total mobile source emissions in the US (ICF, 2005). Many of the nation's largest ports and border crossings are in non-attainment areas for the pollutants to which freight generates substantial contributions. Of the ten largest ports in overall tonnage, seven are non-attainment for one or more criteria pollutants, and all three of the largest border crossings between the US and Canada are non-attainment for one or more criteria pollutants. Freight contributes a significant proportion of the non-attainment pollutants in these areas. For example, eight counties in the Houston area are in non-attainment for ozone. Nitrous oxides (NO_x) are a primary contributor to ozone, and freight contributes 52% of mobile source NO_x emissions and 29% of all NO_x emissions in Houston (ICF, 2005).

Numerous studies have documented the adverse health effects of freight emissions. These range from mild symptoms such as lung and eye irritation to sudden death. Ozone is known to cause respiratory and eye irritation, nitrous oxides and sulfur oxides to cause respiratory damage, and particulate matter to cause respiratory, cardiovascular, and cellular damage.

Diesel particulate matter (PM) contains hundreds of different compounds, and is considered a likely carcinogen (EPA). Health risks from diesel PM are disproportionate to their percentage of total particulate matter. Diesel PM is considered an air toxic, and has been estimated to contribute 70% to 85% of outdoor air pollution cancer risk (ARB 2005, Puget Sound Clean Air Agency 2003). In particular, there is growing concern over one type of PM emissions: ultrafine particles. These particles are small enough to penetrate deeply into body tissues, lodging not only in the lungs, but in blood, organs, and mitochondria (Li et al, 2003). Research on ultrafine particles has been conducted since the 1970s, and there is agreement that ultrafine particles pose some of the most serious dangers to human health. However, understanding of ultrafine particle deposition and its role in human health is incomplete.

Children are especially susceptible to respiratory problems caused by emissions. Studies showed that children living in areas with higher levels of NO_x, PM, and acid vapor had reduced lung development (Am J Respir Crit Care Med 2000). Also, children living in areas with high ozone who actively participated in several sports were more likely to develop asthma than children not participating in sports (Lancet 2002; 359:386 – 391).

The external costs of freight transport, consisting mainly of health effects, are high. One study estimated the external costs of truck transport at over \$3.00 per mile (CORINAIR). Other studies have found much lower values, although it should be noted that the external costs of emissions vary according to the existing air quality (Forkenbrock, 1998).

Due to the health effects of freight emissions and their contribution to smog and noise, many communities and environmental groups have strongly opposed expansion projects at freight gateways. This opposition has the effect of delaying or preventing projects, increasing costs, and contributing to congestion at these gateways. The paradigm has often been “freight vs. air quality”. A new paradigm is needed where freight expansion and air quality improvements co-exist.

The problem of freight emissions and effective mitigation is complicated by a number of misconceptions about freight and air quality. These often lead to responses and approaches which are sub-optimal in terms of results and cost-effectiveness. Misconceptions include:

- “Methods to reduce freight emissions are contrary to industry goals of reducing costs and increasing capacity, velocity, safety, and security.” In fact, many practices which reduce freight emissions reduce costs and/or improve capacity, velocity, safety, and security.
- “The pollutants from freight which need to be reduced are NO_x, SO_x, PM-10, PM-2.5, and greenhouse gases (GHG).” In addition, there is growing awareness of the health hazards of ultrafine PM, which some consider one of the most harmful pollutants. More study is needed on ultrafine PM, but enough is known to describe ways to reduce emissions and reduce exposure to emissions.
- “Only Class 8 trucks need to be considered in efforts to reduce diesel truck emissions.” On a national basis, most diesel truck emissions are from Class 8 trucks, but in many cities, where air quality problems are most common, smaller trucks account for a substantial percentage of total diesel truck emissions.
- “The best approaches are those which result in the greatest total reductions at the lowest cost.” However, the greatest concern with freight emissions is the effect on human health. Therefore, the greatest health benefits are achieved where ambient levels are highest, and where population is concentrated. Reductions in areas with better air quality or lower population have less overall health benefits.
- “Diesel trucks are and will continue to be the largest contributor to freight emissions.” In fact, the freight emissions “landscape” is shifting, as recent EPA standards will result in large reductions in truck emissions over time, leaving locomotives and marine vessels emitting a growing percentage of total freight emissions. Proposed standards for locomotives and small to medium marine engines are likely to effect

similar reductions from these modes, leaving large ocean-going vessels responsible for an even larger share of total freight emissions, primarily in port cities.

- “Current or planned EPA regulations are adequately addressing the problem of freight emissions.” Although recent tailpipe standards for trucks and off-road engines (e.g. cargo handling equipment) and proposed standards for locomotives and category 1 & 2 marine engines will lead to large decreases in these emissions, emissions from ocean-going vessels are expected to increase in many areas. Without similar improvements in ocean going vessel emissions, these will become the dominant source of freight emissions in some areas.

To promote effective mitigation measures and policies, these misconceptions must be corrected, and approaches must be identified which not only reduce emissions, but do so in ways which are economically, institutionally, and politically feasible. Based on freight transportation trends and air quality impacts, this study identifies principles for the evaluation of mitigation practices, provides a comprehensive list of current, pilot, and concept practices, and identifies areas where additional research is needed.

Scope

This study focuses on trucking, rail, and marine transportation. Air freight is discussed only briefly due to its generally minimal contribution to overall freight emissions. Within these modes, the pollutants studied include nitrous oxides (NO_x), ozone, sulfur oxides (SO_x), and particulate matter (PM). The study covers only the trends and environmental effects of freight operations. Environmental effects of the development of freight facilities are not included.

Section 2 examines trends in US international container trade, including overall growth rates and patterns, growth rates by trading partner, concentration at gateways and border crossings, and causal factors of these trends. Trends within each mode are presented separately, along

with an examination of changes in modal shares. The purpose is to identify potential problems in the transportation system, and to provide a background for principles to guide the development and evaluation of mitigation practices.

Section 3 provides information on freight contributions to total emissions on a national and regional basis, along with an examination of air quality at major freight gateways. Trends in emission standards and fuel standards are described and compared across modes for the purpose of showing where the needs and opportunities for improvement are greatest. Section 3 also provides justification for the study's focus on specific pollutants. Section 4 presents principles to guide the evaluation of mitigation practices. Sections 5 and 6 present conclusions and recommendations for further research. The appendix provides a comprehensive list of mitigation practices.

2.0 TRENDS IN U.S. INTERNATIONAL CONTAINER TRANSPORTATION

2.1 Introduction to Container Trends

The trends section serves as background and support to the report's primary focus: the air quality impacts of U.S. international container freight and best practices to mitigate those impacts. The trends section covers the following topics:

- Magnitude of U.S. international container transportation
- Recent trade growth – rates, patterns, causal factors, and projections
- Concentration of volume at large ports and border crossings
- Trends within the modes of ocean, rail, truck, air, and inland waterborne transport

The report focuses on container transportation, only briefly mentioning bulk and general cargoes. This focus is due to the rapid growth of container freight and the lower unit air quality impacts of other cargo types. There is more emphasis on ocean container trade because of the rapid growth, the relatively lower environmental regulation of ocean going vessels, and the resulting tension between needs for capacity and air quality.

Subsequent sections of the report will discuss air quality issues related to container freight transportation, along with principles for evaluating best practices and a list of candidate best practices.

2.2 Magnitude of U.S. International Trade

International trade is a large and growing portion of the U.S. economy. Trade includes both goods and services, but this report focuses only on goods trade. In particular, the paper focuses on container trade, due to its rapid growth and its higher per unit impacts to air quality than other cargoes. Ocean borne container trade is over 27 million twenty foot equivalents (TEU) per year, with another 15 million containers imported by rail or truck. The high volume of ocean borne container trade creates large volumes of truck traffic at major ports. At the ports of Los Angeles and Long Beach, there are over 40,000 truck trips per day. Volume of rail traffic generated is also large. A single vessel of 8,000 TEU, if completely unloaded at a single port, would require 16 double stack intermodal trains to carry all the containers.

Despite the tremendous growth that has occurred in container trade, bulk goods still account for the majority of trade tonnage, with container trade 16.1% of total waterborne U.S. international trade tonnage in 2005, up from 11.8% in 1997 and 14.4% in 2004 (MARAD). The increase in percentage of tonnage comprised of containerized goods will continue as containerized trade growth outpaces growth of bulk goods. See the table below.

Table 1: US International Waterborne Trade, Container vs. Total

Year	Container Tons (million)	Total Tons (million)	Container % Tons
1997	125.3	1062	11.8%
2004	187.2	1297	14.4%
2005	202.4	1258	16.1%

Briefly examining ocean borne cargoes of all types, it is evident that trade varies by region in character, magnitude, and value. Although ports on the west coast often receive the most publicity, the highest overall tonnage occurs at gulf coast ports. Gulf coast trade is the largest in tonnage by a wide margin, at 643 million metric tons in 2004, more than the east coast west coast combined. Despite the high tonnage on the gulf coast, the highest value is on the west coast. As shown in the table below, the value per ton is much higher at west coast and east coast ports than at gulf coast ports. This is due to a higher percentage of manufactured goods on both coasts, vs. more bulk goods such as oil and grains on the gulf coast. Also, there were large variations in growth rates among regions, with the highest growth in value occurring on the gulf coast, and the highest growth in tonnage occurring on the west coast. The tables below give a snapshot of waterborne trade volume and growth by region, and include all cargo types – bulk, break-bulk, and container.

Table 2: Volume of US international Waterborne Trade by Region (MARAD)

Region	Tonnage (1,000 metric tons)	Value (millions)	Value per Ton
West Coast	230,011	\$370,089	\$1,609
East Coast	338,996	\$358,617	\$1,058
Gulf Coast	642,856	\$197,359	\$307
Puerto Rico and VI	42,594	\$15,786	\$371
Great Lakes	52,343	\$6,806	\$130
Total US	1,036,988	\$948,667	\$915

Table 3: US waterborne international freight compound growth by region, 1997 to 2004, MARAD

Region	Value CAGR 1997 – 2004¹	Tonnage CAGR 1997 - 2004
West Coast	4.8%	4.6%
East Coast	6.5%	3.4%
Gulf Coast	8.7%	3.1%
Great Lakes	0.5%	2.2%
Puerto Rico and VI	6.4%	2.7%
Total US	6.2%	3.4%

Notes:

1. Value of waterborne international freight was not adjusted for inflation.

2.3 Recent Trade Growth – Rates, Patterns, Causal Factors

This section describes national and regional patterns of growth, focusing primarily on ocean trade and NAFTA trade. Although these categories overlap to a degree, they can be discussed separately, as the vast majority of NAFTA trade is carried by truck and rail.

In Europe, freight transport measured in ton-miles has been growing faster than GDP. This has been attributed primarily to an increase in the average distance goods travel as a result of concentration of production and inventories, outsourcing, and a wider geographic range for both materials and markets (Runhaar, 2002). In the US, the growth rate of domestic freight, measured in ton-miles, is lower than GDP growth. From 1990 to 2001, the annual growth rate in domestic ton-miles has averaged 2.0 percent. During that same period, the GDP growth rate was 3 percent. One possible explanation for the higher growth of GDP than freight transport is the increasingly service nature of the US economy. Also, while transport between countries in Europe would be included in ton-mile computations, much of the transport between the U.S. and most of its trading partners is not included in the ton-mile growth because it occurs outside the boundaries of the U.S. (in ocean transport).

2.3.1 Container Growth Rates and Patterns

2.3.1.1 Ocean

U.S. international ocean borne container trade experienced a 7.2% compound annual growth rate from 1997 to 2005 (MARAD). At this rate, total container trade (import and export) will double every 10 years. However, due to the imbalance in container trade, with import containers outnumbering exports by 2 to 1, and different growth rate of imports (10.5% CAGR) and export (2.4% CAGR), the first doubling would occur in approximately 8.5 years at these growth rates. This rapid growth puts tremendous pressure not only on ports, but also on connecting road and rail infrastructure.

Growth from 2003 to 2005 was even higher, as shown in the table below which lists growth rates for some of the largest and most rapidly growing container ports. Although container import growth slowed in 2006, export growth has increased sharply, largely due to exchange rates. The high growth rates of U.S. international trade show no signs of abating.

Table 4: Recent Growth Rates at Selected Ports (MARAD)

Port	2003	2004	2005	TEU CAGR '03-'05
Los Angeles, CA	4,663,899	4,874,730	4,864,032	2.1%
Long Beach, CA	3,090,712	3,764,257	4,378,446	19.0%
New York, NY	2,803,036	3,163,197	3,387,305	9.9%
Charleston, SC	1,249,770	1,421,251	1,508,564	9.9%
Savannah, GA	1,124,409	1,290,178	1,469,237	14.3%
Oakland, CA	1,064,278	1,197,331	1,373,769	13.6%
Seattle, WA	814,742	1,049,105	1,339,469	28.2%
Norfolk, VA	1,093,207	1,206,034	1,318,762	9.8%
Houston, TX	932,883	1,097,769	1,221,541	14.4%
Tacoma, WA	931,289	940,638	1,154,834	11.4%

The U.S. is not alone in high growth of container trade. Global Insight forecasts 5.9% annual growth in world container trade from 2005 to 2010, and 5.1% from 2010 to 2015. World container trade is projected to grow from under 90 million TEU in 2005 to approximately 200 million TEU in 2020. Overall tonnage for all cargo types is projected to grow more slowly, with North American ocean borne trade forecast to grow 1.9% per year from 2005 to 2010 (Global Insight, 2005).

As a result of the rapid growth at container ports, the number of ports handling over one million TEU per year has grown sharply from three ports in 1997 to 10 ports in 2005.

Table 5: Number of Container Ports at given volumes (source: MARAD)

Year	Ports ≥ 1K TEU/year	Ports ≥ 10K TEU/year	Ports ≥ 100K TEU/year	Ports ≥ 1M TEU/year
1997	48	37	20	3
2004	44	36	22	9
2005	45	37	25	10

Despite lower growth rates in overall tonnage, some ports which do not handle large volumes of containers are nevertheless growing quite rapidly, as seen in the following table. None of these ports handle large volumes of containers.

Table 6: Selected U.S. Ports with Rapid Tonnage Growth from 2003 – 2005 (MARAD)

Port	2003 Tonnage	2005 Tonnage	Tonnage CAGR '03-'05
Ashtabula, OH	1,228,191	6,758,433	134.6%
Duluth, MN	739,213	3,634,284	121.7%
Superior, WI	2,237,816	9,209,322	102.9%
Chicago, IL	823,971	2,183,253	62.8%
Aberdeen, WA	405,027	736,518	34.8%
Newport News, VA	3,622,763	6,018,872	28.9%
Wilmington, DE	306,396	501,876	28.0%
Texas City, TX	3,638,011	5,645,388	24.6%
San Francisco, CA	1,257,983	1,856,756	21.5%

2.3.1.2 NAFTA Trade Growth Patterns

While much attention has rightly been fixed on China, NAFTA trade (Canada and Mexico) comprises a larger portion of U.S. international trade. NAFTA trade growth has been rapid, with an 18% annual growth rate from 1996 to 2004. Despite the rapid growth of ocean trade, particularly with China, land transportation has been an increasing share of total international trade at 22.9% in 1990 and 28.4% in 2003 (BTS). This growing share is related to NAFTA trade growing at a higher rate than overseas trade.

During this period of growth in NAFTA trade, modal shares have not been constant. While both truck and rail crossing grew rapidly between 1994 and 1999, growth in truck crossings slowed dramatically between 1999 and 2004, to an annual rate of 0.41%, as shown in the table.

Table 7: Incoming Truck Crossings to United States from Mexico and Canada: 1994–2004 (BTS)

Year	Mexico	Canada	Total
1994	2,763,120	4,956,174	7,719,294
1995	2,860,625	5,135,010	7,995,635
1996	3,254,084	5,431,096	8,685,180
1997	3,689,665	5,826,974	9,516,639
1998	3,946,543	6,270,934	10,217,477
1999	4,358,121	6,817,447	11,175,568
2000	4,525,579	7,048,128	11,573,707
2001	4,304,959	6,776,909	11,081,868
2002	4,426,593	6,915,973	11,342,566
2003	4,238,045	6,728,228	10,966,273
2004	4,503,688	6,901,820	11,405,508
CAGR 1994 - 1999	9.54%	6.58%	7.68%
CAGR 1999 - 2004	0.66%	0.25%	0.41%

The most rapid growth in rail container crossings from the United States to Canada and Mexico occurred before 1999. Growth since then has been slower but still substantial:

Mexico Rail Container Crossing CAGR 1999 – 2004: 6.23%

Canada Rail Container Crossing CAGR 1999 – 2004: 5.22%

Given the marked difference between growth in truck and rail crossings, it appears that most of the recent (1999 – 2004) growth in NAFTA trade is via rail. This shift has been attributed

to recent security requirements which have hindered cross-border truck traffic, especially less than truckload (LTL), more than rail (Brooks).

2.3.2 Container Growth by Trading Partner

After years of rapid and sustained growth, trade with China now (2005) constitutes 35% of all U.S. waterborne international container trade, up from 31% in 2004 (MARAD). The CAGR from 1997 to 2005 was 22.3% for import containers, and 21.1% for exports. If this growth rate continues, container trade with China will double in approximately 3.5 years. Although there are factors which could limit this growth (labor shortages, environmental pressures, difficulty sustaining currency manipulation, rising standard of living affecting labor cost advantage, limits of trade relative to goods GDP), trade growth with China showed no signs of slowing until 2006. See the table below.

Table 8: U.S. – China Container Trade Growth in TEUs (MARAD)

Year	U.S. – China Container Trade Growth over Prior Year
2001	14.1%
2002	23.6%
2003	17.5%
2004	30.0%
2005	23.0%
2006	12.8%

Global Insight cites a number of factors which at some point will reduce trade growth with China:

“In the long run, it is impossible for Chinese exports and imports to maintain two-digit growth, unless the trade of other major countries can expand at the same pace. China's manufacturing expansion will gradually meet the limit of world demand; the price of energy will continue to rise; raw materials and labor will gradually diminish China's cost advantage; and the rapid manufacturing expansion will deteriorate China's environment to the extent that further manufacturing expansion is much more difficult.” (GI)

Among the largest trading partners, trade growth is next highest with India. From 1997 to 2005, container trade with India increased at 13.0% CAGR, with imports growing at 13.3%. It is worth noting that while the CAGR in container trade with India was 13.0% from 1997 to 2005, the CAGR from 2000 to 2005 was 15.5%. At an annual growth of 15.5%, container trade with India would equal the current (2005) container trade with China in twenty years, which would clearly have major ramifications for transportation infrastructure.

A number of other countries are experiencing even higher rates of trade growth. Container trade with Vietnam has grown at 37.3% CAGR from 1997 to 2005, Turkey at 13.8% CAGR, and Pakistan at 14.4% CAGR. Import growth rates are even higher. Containerized imports with Vietnam have grown at 42% CAGR from 1997 to 2005. Most of the trade growth with Vietnam occurred from 2001 to 2005, during which period the CAGR was 68%.

If current growth rates for container imports with each trading partner continue (e.g. 22% CAGR in China imports, 13% for India, 42% for Vietnam, etc.), container imports will double in **5 years**, from ~17M in 2005 to ~35M in 2010. Total trade would double in just over 5 years. Although these growth rates are probably not sustainable in the long run, there is little indication of the growth slowing anytime soon. Even if overall U.S. container trade takes 10 years to double, import container trade appears likely to double significantly sooner. Some constraints of the transportation system may be linked to the higher of imports or exports, rather than to the total, e.g. drayage truck trips, handling and storage of empties.

Therefore, the need to double some elements of freight capacity may occur in substantially less than 10 years.

The table below shows container trade volumes, rankings, growth rates, and volume projections at current growth rates for the largest trading partners, and also for some of the fastest growing trading partners. The projection for 2010 is for illustrative purposes only, and is NOT a forecast. It only shows what **would** happen if the import and export TEU growth rates with each trading partner which occurred from 1997 to 2005 were sustained through 2010. The total for all countries is based on a cap of 50% CAGR, even though actual growth with some smaller trading partners has exceeded 50%. This cap did not affect projections for any of the countries listed in the table below, but did affect several smaller trading partners. TEUs are in thousands except as otherwise indicated.

Table 9: U.S. Container Trade with Largest and Fastest Growing Trading Partners (MARAD)

Rank by Total TEUs		Country	CAGR 1997 - 2005		Total TEUs		Projection* at '97-'05 CAGR
1997	2005		Import	Export	1997	2005	2010
1	1	China	22.3%	21.1%	1,835	9,041	24,503
2	2	Japan	1.8%	-2.8%	1,760	1,661	1,629
3	3	Hong Kong	3.4%	-4.8%	1,120	1,156	1,237
6	4	South Korea	8.9%	1.3%	690	1,007	1,329
4	5	Taiwan	0.4%	0.7%	941	981	1,008
5	6	Germany	7.1%	2.7%	470	726	966
10	7	Brazil	12.4%	-3.4%	418	658	1,016
13	9	Thailand	8.5%	2.2%	327	552	782
24	10	India	13.3%	12.3%	191	507	933
64	17	Vietnam	42.0%	24.6%	23	285	1,511
34	25	Turkey	15.4%	12.2%	84	237	456
43	30	Pakistan	15.9%	11.0%	52	152	303
		All Countries			14.9M	25.9M	47.3M

* The projection is NOT a forecast, but illustrates the potential for a near doubling of ocean borne container volumes in just over five years if the high growth rates with many of the largest trading partners continue.

2.3.3 Trade Imbalance and Empty Containers

With the imbalance of container trade, many containers leave the U.S. empty. As a result, freight rates for containerized exports are lower than for imports. Because of these available containers and lower pricing for export containers, some goods are now being containerized more than previously, as carriers search for available markets for these otherwise empty export containers. While this may benefit exported goods, it creates difficulties for ports and shippers.

With container imports outnumbering exports by 2 to 1, ports require additional terminal space to store the empties, and additional moves to take them off the main terminal. The empties are not always picked up promptly, and some are even sold for scrap, or used for other (non-transportation) purposes. The problem of empty containers will worsen due to the increasing imbalance of trade. If the growth rates of imports and exports from 1997 to 2005 were to continue, import containers would outnumber exports by 9 to 1 in 20 years, dramatically increasing the problem of empties.

2.3.4 Factors Driving Growth

This section discusses selected factors which affect the growth and character of freight transportation. A major driving force behind many trends is business cost reductions. Cost reduction motivates globalization, inventory reduction, which in turn affect freight transportation. Increased vessel sizes and concentration of ownership in the marine terminals and ocean carrier industries are also driven by the desire to reduce costs. These trends do not directly affect trade growth, and will be discussed in the Modal Trends section of the report.

Economics drive nearly every aspect of freight transportation. For passenger transport, the factors influencing travel are numerous, such as desire for mobility and independence,

recreation/leisure, and many other aspects. But for freight, goods only move when there is an economic incentive to do so. The mode choice, frequency of shipment, level of consolidation, own-transport or contracted, route, date of shipment, required date of arrival, and all other variables are determined by business needs. To understand freight movement and trends, two economic factors driving decisions by shippers and carriers will be examined briefly.

2.3.4.1 Inventory Reduction

The desire to reduce inventory is motivated by cost reduction. Just in time (JIT) production and JIT distribution are both means to accomplish this reduction of inventory and costs.

These costs include:

- Lower holding costs, which affect return on investment;
- Lower product storage and handling costs;
- Less risk of products becoming obsolete or being lost, damaged, or stolen;
- Less manufacturing and transportation of unsold products.

Reduced inventory may be important not only for individual firms to control costs, but may also contribute to a more stable economy. Recapping an article from the May 2002 issue of the Economic Policy Review, authors James A. Kahn, Margaret M. McConnell, and Gabriel Perez-Quiros state “The authors conclude that more effective inventory management explains much of the increased stability of GDP growth. In their view, advances in information technology have enabled firms to anticipate changes in demand, and thus to avoid the extreme swings in inventory that can contribute to output volatility.” As a result of efforts to reduce inventory, the inventory to sales ratio of durable goods has fallen 30% since the early 1980s (ibid).

The reduction of inventories has a number of effects which in turn affect transportation. These include warehouse consolidation, large national and regional distribution centers (DCs), cross-docking, and the need for increased velocity, reliability, and visibility. The need for velocity and reliability affects mode choice, reducing the waterborne share of domestic freight, and limiting potential shifts from truck to rail. This need is also behind the strong growth in air cargo. Some businesses carry no inventory, utilizing overnight delivery from their supplier to fulfill customer orders.

2.3.4.2 Globalization

The US economy is increasingly part of a global economy. Not only are raw materials and finished goods imported and exported, but large quantities of work-in-process goods move between the US and other countries. Often, these international moves of goods are within a multi-national company, where different parts and sub-assemblies of the final product are manufactured in different countries. Globalization, motivated by the desire to reduce production costs and increase markets, is enabled and “fueled” by trade liberalization, decreasing transportation costs, improved information and communication technology, and economic growth.

2.4 Trade Concentration at Key Gateways

It has been suggested that trade volumes are concentrating at the largest ports and border crossings. If so, the concentration would have significant implications for transportation infrastructure, land requirements, port productivity, and environmental impacts. Can this claim be supported based on available trade data? This question will be examined for ocean borne trade, and to a lesser degree for border crossings.

2.4.1 Concentration at Ports

First, we will examine whether total ocean borne trade tonnage is concentrating at the largest ports. MARAD data from 1997 and 2004 were examined for both tonnage and value of trade. As shown in the tables below, the percentage of total ocean borne trade tonnage handled by the largest ports was constant from 1997 to 2004 at 69.7%. In the same period, total value of ocean borne commerce handled at the top twenty ports declined slightly from 83.7% in 1997 to 82.1% in 2004.

Concentration of total trade for all cargo types does not appear to be significant, if any.

The main exceptions to tonnage concentration are the ports of New York and Houston, which have increased their percentage of total trade during this period. One exception to value concentration is the port of Los Angeles, which has increased its percentage of total trade value. While a few ports are experiencing rapid growth, overall trade concentration is not occurring for either tonnage or value.

Table 10: Percentage of Trade Tonnage at Largest U.S. Ports (MARAD)

Number of Ports	% of Total Tonnage 1997	% of Total Tonnage 2004
Top 5 Ports	31.5%	30.7%
Top 10 Ports	47.7%	48.8%
Top 20 Ports	69.7%	69.7%
Top 50 Ports	90.8%	92.2%

Table 11: Percentage of Trade Value at Largest U.S. Ports (MARAD)

Number of Ports	% of Total Value 1997	% of Total Value 2004
Top 5 Ports	47.7%	49.1%
Top 10 Ports	66.3%	64.8%
Top 20 Ports	83.7%	82.1%
Top 50 Ports	96.4%	97.2%

While total ocean borne trade tonnage and value are not concentrating, ocean borne container trade has been concentrating at the largest ports. As seen in the table, container volume in TEUs at the ten largest ports increased from 79.8% in 1997 to 83.9% in 2004 and just over 85% in 2005. Comparison between the same years for the top five and top twenty ports also showed an increase in the percentage handled by the largest ports. Factors contributing to this concentration will also be discussed briefly in a later section of the report.

Table 12: Percentage of Container Volume at Largest U.S. Ports (MARAD)

Container Trade Volume, TEUs	% of Total TEUs 1997	% of Total TEUs 2004	% of Total TEUs 2005
Top 5 Ports	56.9%	60.9%	60.3%
Top 10 Ports	79.8%	83.9%	85.1%
Top 20 Ports	95.8%	96.4%	96.4%
Top 50 Ports	99.995%	99.997%	99.993%

Not only are container volumes becoming more concentrated, they are much more concentrated than ports overall. While the largest twenty ports in overall tonnage comprised 70% of the total, the top twenty container ports comprised over 96% of total TEU volume.

This concentration should be considered when evaluating highway, rail, and port infrastructure investments.

Terminal productivity, measured in TEU per acre and TEU per berth-foot, is substantially higher in many Asian and European ports than in the U.S. The rapid growth of container volumes at load center ports, coupled with limited availability of land for expansion, will require improvement to U.S. port/terminal productivity. Since higher productivity requires greater capital expenditures for automation and other measures, the concentration of volumes will increase pressure for capital at these load center ports.

2.4.2 Concentration of Border Crossing Traffic

Just as container volumes are concentrated at a small number of key gateways, surface trade is also concentrated at a small number of border crossings. The ten largest land gateways account for about three-fourths of surface trade by value. Given this level of concentration, it is not surprising that long delays can occur at these crossings. While noteworthy efforts are made to reduce congestion, such as real-time information about delays being posted online, increased security requirements can have the opposite effect. Changes in the level of concentration at border crossings were not examined.

2.4.3 Factors Contributing to Concentration of Container Volumes

Ocean borne container trade is increasingly concentrated at the largest ports. There are a number of factors which contribute to this concentration, including:

- Larger vessel sizes;
- Environmental requirements;
- Warehouse consolidation;

The increasing size of containerships has many effects on ports. First, larger vessels require greater depth in channels and harbors. Dredging is required both for maintenance and to accommodate larger vessels. At present, only a small number of U.S. ports can accommodate the largest containerships, which require 50 foot depth. Also, dredging costs have increased dramatically in recent years due to environmental requirements. In one rather extreme example, some dredged material in Oakland is being carried sixty miles out to sea. Requests for dredging exceed the Army Corps of Engineers' ability to fulfill them.

The larger containerships ("super post-Panamax") can be 10,000 TEU or more, and need larger and more expensive cranes with a longer reach due to the greater beam of the vessels. Larger, heavier, and faster cranes often require strengthening the wharf which adds to the cost. The escalating costs of handling increasing volumes, larger ship sizes, and meeting environmental regulations makes it difficult for all but the larger ports to make the necessary investments. Also, while port investment requirements are increasing, the useable lifespan of some investments such as wharf structures is decreasing (TNO, 2005).

Another factor in port concentration is warehouse consolidation. Many firms are building regional and even national distribution centers, rather than having smaller and more numerous centers with greater geographic diversity. These large distribution centers, which are sometimes over one million square feet, are typically located near large ports and interstate highways. The trend toward larger distribution centers thereby contributes to the concentration of container volumes at the largest ports.

2.5 Modal Trends

The modal trends section of the paper describes trends in each of the following freight modes: ocean; rail; truck; air. Inland waterborne and pipeline transportation are not covered.

2.5.1 Trends in Ocean Container Transport

One of the most significant developments in ocean container transport has been the dramatic increase in vessel size. Only a few years ago, a 6,000 TEU vessel was considered large. Orders for vessels over 10,000 TEU are now becoming common, with some as large as 13,000 TEU. These sizes approach the technical limits of single engine propulsion, with main engines over 100,000 horsepower. The increase in vessel size reduces costs. Cost (not price) of container transport from Asia to Europe was estimated at \$324 for a 6800 TEU vessel, compared to \$283 for an 8800 TEU vessel (Ocean Shipping Consultants, 2005). The larger size of vessels also increases the peak demand for container handling and truck traffic at the port.

The percentage of Asia to east coast volume traveling by all-water routes has been increasing (Panama Canal Authority, 2006) despite the current limitation of approximately 4500 TEU vessels through the locks of the Panama Canal. This trade lane has been gaining market share over Asia to east coast land bridge traffic (crossing the continent by rail or truck to the east coast). Part of this growth has been due to shippers desire to find alternate routes following the 2002 west coast port labor lockout which effectively closed 29 ports for ten days.

Asia to east coast traffic via the Suez Canal has also been increasing, with several carriers recently adding routes. Although this traffic is still relatively small, it is expected to grow. The increasing availability of large post-Panamax (greater than ~4,500 TEU) vessels enables this route to be cost-effective. East coast container volumes have been growing more rapidly

than west coast volumes, and use of the Asia to Suez to east coast route will add to this growth.

Another trend in ocean transport is the containerization of goods which traditionally have been bulk or break-bulk. Examples include grain, oil, and oranges. In Vancouver, imported containers which would otherwise return empty are used to ship specialty grains. Authors Rodrigue and Slack state: “technical improvements tend to blur the distinction between bulk and break-bulk cargo, as both can be unitized on pallets and increasingly in containers. For instance, it is possible and increasingly common, to ship grain and oil, both bulk cargoes, in a container...”

Security requirements are having a large effect on port operations and costs, in addition to providing challenges to capacity. Bernard Groseclose, CEO for the South Carolina States Ports Authority said "Security has been the fastest growing and least controllable cost we have had over the last couple of years," acknowledges. (World Trade, Dec 2004)

Congestion is sometimes a concern at U.S. ports, particularly on the west coast. Delays frequently occur at the gate, and sometimes waiting for a berth. Given the tight delivery requirements of shippers, these delays are a concern, adding to the cost of business operations by affecting inventory levels. The west coast labor “lockout” of 2002 shut down 29 ports on the west coast, causing long delays, with many vessels waiting in the harbors. As a result, many shippers have sought alternative routes for cargo, which has increased growth at east coast ports.

As has occurred in many industries, ocean carriers are consolidating through mergers and acquisitions. A small number of carriers now control the majority of container capacity. Vertical integration is also occurring as some firms operate as ocean carriers, terminal operators, and even trucking and logistics providers. For example, Overseas Orient Container Line owns terminals in Long Beach and New York. In Asia and Europe, OOCL

also offers rail service. APM (Maersk) owns terminals in a number of cities worldwide, including Baltimore, Charleston, Houston, Los Angeles, and Miami. Some terminal operating companies are investing in infrastructure in Mexico, both in ports and in rail. An example is investment in the Mexican port of Ensenada by Hutchinson and investment in north-south rail lines. Motivation for this vertical integration includes both cost reduction and ensuring the availability of capacity in the event of congestion.

2.5.2 Trends in Rail Container Transportation

The rail industry is characterized by a number of paradoxes. In operations, delays and lower reliability are widely understood to hinder the growth of rail. In order to compete more effectively with trucking, higher speeds and more non-stop routes (vs. hub & spoke) are needed (Giradot, CSX). Yet, in the midst of declining average speeds (AASHTO, 2003) and bottlenecks and delays at ports, grade crossings, and border crossings, intermodal traffic has been growing rapidly. Regarding finance, concerns are often raised about the availability of capital for expansion, and carriers sometimes seek innovative financing and partnerships. At the same time, major expansions by Class 1 rail carriers are occurring, double- and triple-tracking key routes. While expansions are occurring, total trackage is decreasing (trackage only counts route length, not adding for multiple tracks).

Key hindrances to growth cited by rail executives include a shortage of land to expand rail yards (which are often in urban areas), financial constraints, and zoning and environmental issues including community opposition based on environmental concerns. Environmental regulations and community opposition not only delay construction and slow capacity increases, but also increase costs. This opposition is somewhat surprising given the environmental benefits of adding rail traffic instead of adding a much larger number of trucks. There appears to be a lack of public awareness of the environmental and congestion benefits of rail transportation. Despite these challenges, intermodal volumes are growing and expansions are taking place.

Other trends in freight rail include an Increase in average train length from 131 units per train in 2002 to 150 units per train in 2005 (BNSF), substantial rate increases, and shorter contracts.

2.5.3 Trends in Trucking

Although not as dramatic as the growth in ocean trade and NAFTA trade, domestic trucking continues strong growth. Truck vehicle miles traveled (VMT) is growing at 3% per year, which is higher than the growth rate for overall highway VMT. Since lane miles are not growing significantly, the result is increasing congestion, as cited by many studies.

Congestion is among the issues which affect and concern the trucking industry. Concerns include driver shortages, the imbalance in import and export containers, and a lack of sufficient port, highway, and rail infrastructure (Bruner). Lack of adequate funds for highway maintenance and construction is a growing concern not only of transportation officials, but also of carriers and shippers, who require a reliable transportation system. The lower velocity and reliability caused by highway congestion increases inventory costs, and some firms have reported recent increases in inventory for this reason.

Some industry representatives believe that driver “shortages” are really a turnover problem. The turnover rate in the trucking industry has recently been 100% - 200% per year in larger trucking firms (Spencer). Congestion and delays contribute to lower profitability in the trucking industry, and thereby contribute to driver shortages. Congestion also lowers the effective capacity of the highway system, thereby creating a need for more drivers. While driver shortages could be addressed by allowing Mexican trucks to operate further into the U.S., the pilot program which allows this is a concern. This program, if expanded, could have major ramifications for the trucking industry.

2.5.4 Trends in Air Cargo

2.5.4.1 Size and Importance of Air Cargo

Air freight represents a substantial portion of U.S. international trade by value, but not by weight. Air cargo has grown from 22.7% of international trade value in 1990 to 26.4% in 2003 (BTS). Measured in tonnage, air cargo is approximately ½% of U.S. international trade. Even with the expected strong growth in air cargo, it will remain a small percentage of trade tonnage.

Despite its small percentage of overall freight tonnage, air cargo has important effects on the nation's transportation system and on the environment. The significance of air cargo to the transportation system and air quality impacts lies in the following:

- Growth in air cargo may lead to congestion at airports, as it competes with growing passenger volumes. Air freight (domestic and international) accounted for 10.1% of aircraft departures in 2002 (ICF, 2005). Although air cargo often moves at night when congestion is less of a concern, nighttime noise is particularly concerning to nearby residents.
- Air cargo consumes a percentage of freight energy which is disproportionate to its size, and also produces disproportionate amounts of greenhouse gases. Air freight uses more fuel than domestic waterborne and rail combined, and about 1/3 as much as trucks. (ICF, 2005)
- A recent study indicates that emissions from night-time flights have a much greater greenhouse effect than daytime flights (Nature, 2006). Night flights are common for air cargo.

2.5.4.2 Air Cargo Growth and Trends

Air cargo has experienced strong growth in recent years, at 7% CAGR from 1990 to 2000 (BTS). Another source indicated that freight and express Revenue Ton Miles (RTM) nearly doubled from 1994 to 2004 (ATA, 2005), implying an annual growth rate of 7% for this period also. Compare this to the much lower growth rate of waterborne tonnage at 3.36% CAGR from 1997 to 2004 (MARAD).

Industry forecasts project continued high growth rates, with Boeing predicting a tripling of volume in the next twenty years:

“Based on three decades of Boeing economic analysis and modeling experience, the industry reference Boeing World Air Cargo Forecast projects that rising world GDP will drive an average 6.2% annual growth in demand for air cargo transport. At this average growth rate, air cargo transport demand will triple in 20 years. While demand for air cargo transport will triple, the number of freighters in the world fleet will only double. Air cargo demand and the freighter fleet grow at different rates because some demand may be met by using larger freighters, rather than by increasing the number of airplanes. Some demand will also be absorbed by the passenger airplane fleet, whose revenue cargo capacity will also grow during the forecast period.” (Boeing, 2006)

The Federal Aviation Administration is also forecasting rapid growth in international air cargo (Bingham, Brooks, Harrison). However, the growth in domestic air cargo slowed dramatically in 2005, apparently due to increased fuel prices. Ton-miles of U.S. air carriers increased 7.5% in 2005, with a 1.6% decrease in domestic ton-miles and a 14.8% increase in international ton-miles. The decrease in use of domestic air cargo is due to a shift from air to ground transportation and the effect of fuel surcharges (FAA).

Air cargo is carried in passenger aircraft and in all-cargo aircraft. Security requirements are making it more difficult to carry cargo on passenger airplanes, and have caused a shift of some cargo from passenger aircraft to all-cargo aircraft. In 2005, 70.8% of total air cargo ton-miles were on all-cargo carriers (FAA). As a result of increasing security requirements, it is expected that the percentage of air freight carried on all-cargo flights will continue to increase.

2.5.5 Modal Shares and Trends

Concerns have been raised that rail could lose market share to trucking unless substantial public or public-private funding is provided for rail infrastructure improvements. However, class I railroads are pursuing expansion, and recent intermodal growth has exceeded the growth of trucking. There are a number of factors behind the higher growth, but one factor is the much higher fuel efficiency of rail over trucking. Increases in fuel prices increase the cost advantage of rail over trucking.

Use of domestic waterborne freight has been declining. In 1990, domestic waterborne represented 31.9% of domestic ton-miles, but decreased to 19.5% in 2001 (ICF, 2005). The low velocity of inland water transportation makes it impractical for many cargo types. Also, maintenance issues (e.g. locks) have hindered the inland waterway system.

3.0 ENVIRONMENTAL EFFECTS OF FREIGHT TRENDS

The purpose of this section is to provide an overview of the relationship between freight and air quality in the US, the expected and potential air quality impacts of recent trends in goods movement, and to provide a framework for identifying and evaluating best practices.

3.1 Primary Pollutants from Freight and Health Effects

There are currently six criteria pollutants defined by the National Ambient Air Quality Standards (NAAQS): ozone, carbon monoxide (CO), nitrogen dioxide (NO₂), sulfur dioxide (SO₂), particulate matter (PM), and lead. Two standards exist for particulate matter: PM-10 for all particles less than 10 microns, and PM-2.5 for particles less than 2.5 microns (fine particles). No separate standard has been established for ultrafine particles, which have diameter less than 0.1 microns.

This study focuses on nitrous oxides (NO_x) and particulate matter (PM), and to a lesser extent, sulfur oxides (SO_x) and carbon dioxide (CO₂). The reasons for this focus are as follows:

- Freight contributes a large percentage of mobile source NO_x and PM emissions, but a small percentage of CO emissions.
- Motor vehicles, including diesels, do not contribute to lead emissions (since the removal of lead from gasoline).
- Although all areas of the US are now in attainment for NO₂, nitrous oxide emissions are a primary contributor to ozone and many areas of high freight activity are non-attainment for ozone.
- Sulfur oxides (SO_x) contribute to the formation of ozone and PM.
- Some areas of high freight activity are non-attainment for PM.

- Diesel PM emissions are considered the most damaging to human health, possibly at levels below current standards.
- Most areas of high freight activity **are** in attainment of NAAQ standards for CO and SO₂, with the exception of Los Angeles and El Paso for CO.
- Greenhouse gases are not currently regulated by EPA, and are covered in a related project. Refer to the Greenhouse Gas Guidebook.

The following definitions of particulate matter are provided for reference:

<u>Particle Type</u>	<u>Particle Diameter</u>
Coarse	2.5 – 10 µm
Fine	0.1 – 2.5 µm
Ultrafine	< 0.1 µm (100 nm)
Nano	< 50 nm

The table below summarizes the health effects of the freight-related pollutants examined in this study.

Table 13: Key Freight-Related Pollutants and their Health Effects

Pollutant		Potential Health Effects
NO _x		Respiratory, lung damage
PM	PM-10	Respiratory
	PM-2.5	Respiratory, cardiovascular, early death
	Ultrafine	Respiratory, cardiovascular, mitochondria structural damage, oxidative stress
SO _x		Respiratory, permanent lung damage
Ozone		Respiratory, eye irritation

3.2 Dispersion Characteristics

NO_x, SO_x, and PM (except for ultrafine) can all affect areas distant from the sources. For example, large urban areas including Los Angeles are believed to contribute much of the haze which sometimes occurs over the Grand Canyon. Only ultrafine PM is limited to short distances in its effects, decreasing to background levels at 300 meters (Sioutas, Delfino, Singh, 2005). Regarding the long distance transport of pollutants, the Geophysical Fluid Dynamics Laboratory (part of NOAA) reports that:

“While US agencies currently focus on US pollution and its impact on human health and agricultural productivity, it is becoming clear that the intercontinental transport of pollution, specifically ozone (O₃) and its precursors (e.g. NO_x, CO) and fine particles (PM_{2.5}), plays a significant role in both US air quality and the regional radiative forcing of climate. It is critical that we develop the capability to evaluate both current impacts and possible future impacts due to increased emissions resulting from further economic development in Asia.”

However, it should be noted that dispersion of pollutants is an area of debate. Some argue that NO_x and SO_x emissions from marine vessels only cause harm when close to land.

3.3 Rationale for the Scope of the Study

3.3.1 Focus on Air Quality

The focus of the report is air quality. Although many environmental issues affect and are affected by freight development and operations, air quality is generally considered the most critical in terms of human health, and is often (but not always) the basis for opposition to freight projects. Within the focus on air quality, the emissions of primary concern are NO_x, PM, SO_x, and increasingly, GHG. The reasons are listed in section 3.3.2.

3.3.2 Focus on Containerized Goods

All sections of this study focus primarily on container transportation. The reasons are as follows:

- Container trade is growing rapidly, with a much higher overall growth rate than bulk or break-bulk cargoes. In addition to the increase in container trade, both the imbalance of trade and cargo routings contribute to a growing volume of empty container moves.
- Bulk goods cause less impact to air quality, at least on a per ton basis, due to:
 - The site of production, processing, and use of many bulk goods is often at a port, along an inland waterway, or has direct rail access. This results in fewer movements, much less use of trucking, and lower impacts to air quality.
 - One of the significant air quality impacts of dry bulk goods, dust, has effectively been mitigated at many facilities by covering.

3.3.3 Focus on Operations

The air quality impacts of freight facility development, while significant, are different than those of operations. Since the majority of freight emissions are related to operations, this report focuses on operations.

3.3.4 Study Limitations

The report covers trucking, rail, and marine. Cargo handling equipment and air freight are discussed only briefly. Emissions from ocean going vessels while distant from land may affect air quality in the US, but that topic is beyond the scope of this study. The effects of increasing congestion on freight emissions were not studied. Ultrafine PM emissions are the subject of considerable research and discussion. Due to limited data on ultrafine emissions, and the lack of a consensus on acceptable levels of exposure, ultrafine emissions are discussed briefly and qualitatively. Data on PM-2.5 emissions is more limited than data on PM-10.

3.4 Freight and Air Quality Background

3.4.1 Freight Contribution to US Emissions

3.4.1.1 NO_x Contribution from Freight

Freight contributions to total US NO_x emissions are substantial, estimated for 2002 at half of mobile sources, and one-fourth of all sources (ICF). Contributions of trucking, rail, marine, and air freight are given in the table below. Trucking contributes most of freight NO_x emissions (67%), and marine vessels contribute the next largest share of freight NO_x emissions (18%). Freight contributions to total emissions have been growing due to strong growth of freight and relatively lower regulation of freight vehicles than other sources, especially ocean going vessels (ICF).

3.4.1.2 PM-10 Contribution from Freight

Although freight contributions to PM emissions from all sources is low (less than 1%), diesel PM emissions are more harmful than other sources such as agriculture, wildfires, and fugitive dust (dust that does not come from definable point sources), which account for the vast majority of PM-10 emissions. In fact, despite the small percentage of total PM emissions, diesel PM is considered the largest contributor to cancer risk from outdoor air pollution, with some studies estimating 70-85% of total outdoor air pollution cancer risk (see section 3.2.1). Freight contributes almost one fourth of mobile source PM-10 emissions, with trucking being the largest share (65% of freight PM-10 emissions). Marine vessels contribute the next largest share (24% of freight PM-10 emissions).

The following table shows freight contributions, by mode, to mobile source and total emissions of NO_x, PM-10, and GHG.

Table 14: Freight Contribution to GHG, NOx, and PM-10 Emissions, by Mode (ICF, 2005)

Mode	GHG		NOx Emissions		PM-10 Emissions	
	% of All Mobile Sources	% of All Sources	% of All Mobile Sources	% of All Sources	% of All Mobile Sources	% of All Sources
Heavy Duty Vehicles	19.2%	4.9%	33.0%	17.9%	23.3%	0.5%
Freight Rail	2.2%	0.6%	7.5%	4.1%	4.1%	0.1%
Marine Vessels	2.6%	0.7	8.8%	4.8%	8.5%	0.2%
Air Freight	0.7%	0.2%	0.1%	0.0%	0.1%	0.0%
Totals	24.7%	6.3%	49.4%	26.8%	36.0%	0.8%

3.4.1.3 Greenhouse Gas Contribution from Freight

Again, freight contributions to GHG are significant, at approximately 25% of mobile sources, and approximately 6% of all sources (ICF). The largest portion of freight's 25% of mobile sources is from trucking, at 78% of freight GHG. Rail and marine GHG emissions are much lower, with roughly 10% each of total freight GHG emissions.

Although air freight GHG emissions are much lower, at less than 3% of total freight GHG emissions, contrails (condensation trails) can spread into cloud cover, with a greater effect than would occur merely from the amount of GHG emitted (EPA). Also, many freight aircraft fly at night, when the effects of aircraft emissions are greater. A recent study in the UK indicated that night flights, while accounting for only 25% of total flights, accounted for 60 – 80% of flight-related GHG warming effects (Nature, 2006).

3.4.2 Freight Contribution to Regional NOx and PM Emissions

In some regions, freight accounts for a larger percentage of NOx emissions. Freight NOx emissions range from 31% to 39% of all sources in five regions analyzed in the ICF study. This compares with freight contributing 27% of NOx emissions from all sources nationally.

As with NOx, freight contributions to total PM emissions varies by region, and is significantly higher than national averages in some locations. Regional PM-10 contribution from freight varies from 22% to 47% of mobile sources, compared to 36% nationally. (PM-10 emissions are compared here to mobile sources, whereas NOx emissions figures are for all sources. This is because mobile source PM is more harmful than other sources of PM.) The

table below shows freight contributions to NOx and PM emissions at five major freight gateways.

Table 15: Regional Freight NOx and PM-10 Emissions (ICF)

Region	Freight NOx Emissions		Freight PM-10 Emissions	
	% of Mobile Sources	% of All Sources	% of Mobile Sources	% of All Sources
Chicago	50.6%	34.1%	39.9%	5.8%
Dallas-Ft. Worth	40.5%	34.9%	22.3%	1.0%
Detroit	51.2%	30.8%	41.5%	2.2%
Houston	52.1%	28.9%	47.2%	1.7%
Los Angeles	43.4%	39.1%	26.9%	1.8%

3.4.3 Freight Contribution by Activity

Truck

Freight emissions for each mode can be classified by activity (e.g. line haul rail vs. yard operations). These classifications can be helpful in terms of gauging the potential benefits of mitigation measures which do not apply equally across all activities, e.g. measures which reduce idling emissions but not other activities. The tables below, one each for truck, rail, and marine, provide estimates of emission contributions by activity.

For long haul heavy duty trucks, approximately 90% of NOx emissions occur with the truck at cruise speed. Therefore, for overall NOx reductions from these vehicles, efforts should be focused on those measures which are effective at cruise speed. Note, however, that idling emissions sometimes occur in more sensitive areas than emissions at cruise.

Table 16: Emissions by Activity, Long Haul Heavy-Heavy-Duty Diesel Trucks

Activity	NOx Emission Factor (g/min)¹	% Time¹	% of Total Emissions²
Idle (0 mph)	1.2	39.5%	4.6%
Creep (0-10 mph)	2.21	3.3%	0.7 %
Transient (11-45 mph)	6.53	7.6%	4.8%
Cruise (> 45 mph)	18.69	49.6%	89.9%

Notes:

1. Source: Analysis Of Heavy-Duty Diesel Truck Activity And Emissions Data: Huaia, Shah, Miller, Younglove, Chernichb, Ayalab, Atmospheric Environment 40 (2006) 2333–2344
2. Calculated based on emission factor and % time in activity

Rail

The following table, for RR emissions by activity, indicates that in some areas, emissions from yard operations are a large percentage of total freight rail emissions. For example, in Baltimore, yard operations are estimated to contribute over 50% of freight rail NOx and PM-10.

Table 17: Yard Operation as % of Total Freight Rail Emissions (ICF)

Region	NOx	PM
Baltimore	54%	52%
Chicago	18%	32%
Dallas	27%	26%
Detroit	25%	23%
Houston	31%	29%
Los Angeles	10%	8%

Marine

The table below shows marine emissions by activity. It is based on data from California, and includes all marine emission within 24 miles of shore. Over 80% of NO_x, PM, and SO_x emissions are from transit as vessels travel between ports. Values may differ substantially for other areas, due to variations in the amount of coastal vessel traffic, and atmospheric conditions which would affect the distance from shore where emissions affect air quality on shore. The data does not include the effects of recent mitigation measures.

Table 18: Marine Emissions by Activity (CARB)

Mode	NO_x	PM	SO_x
Hoteling	16%	16%	17%
Maneuvering	2%	3%	2%
Transit	82%	81%	81%

The next table shows OGV emission factors at different engine loads, based on testing on the Sine Maersk, a large (6600 TEU) containership built in 1998. Only 12% load is required for a speed of 12 knots; doubling vessel speed to the 24 knots typical of newer container vessels requires a six-fold increase in power, and a resulting large increase in emissions and fuel consumption. This gives an indication of the potential effectiveness of vessel speed reduction to reduce emissions.

As seen in the table, emissions per unit of energy produced are somewhat lower for NO_x and HC at higher engine loads. However, this is more than offset the by much larger difference in power requirements at different speeds. For example, 12 knots requires only 12% power, compared to 24 knots which requires 78% power, or over six times as much power to go only

two times as fast. Therefore, emissions per mile will be much lower at reduced speeds. Including both the higher emission factors at lower engine speeds and the increased emissions from auxiliary engines (due to spending more time within 24 miles of shore), NOx emissions were estimated to be reduced by 60% by reducing vessel speed from 24 knots to 12 knots within 24 miles of shore (Summary of Sine Maersk Testing, CARB).

Table 19: Main Engine Emissions (g/KW-Hr), CARB

Pollutant	Engine Load (Speed in Knots)				
	86%	78% ¹ (24)	53%	25%	12% ¹ (12)
NOx	20.7	20.3	20.4	23.1	24.2
PM	1.97	1.80	1.55	1.36	1.51
HC	0.08	0.09	0.12	0.14	0.21
CO	0.17	0.17	0.20	0.29	0.36

Source: Summary of Sine Maersk Testing, California Air Resources Board

Notes:

1. 12% engine load corresponds to 12 knots, 78% to 24 knots.

3.4.4 Air Quality at Major Gateways

The purpose of this section is to provide an overview of air quality, measured by NAAQS, at major freight gateways:

Container Ports (section 3.4.4.1)

Other Large Ports (section 3.4.4.2)

Border Crossings (section 3.4.4.3)

Inland Freight Hubs (section 3.4.4.4)

Freight Contributions to Emissions at Gateways (section 3.4.4.5)

The contribution of freight to the non-attainment pollutants in some of these areas will be examined briefly. It will be shown that the freight contribution to criteria pollutants varies considerably both by region and by pollutant.

3.4.4.1 Air Quality at Major Container Ports

The table below shows the largest 25 container ports in the US, those which had TEU volume above 100,000 in 2005. The compound annual growth rate in TEU volume for each port from 2000 to 2005 is also shown, along with attainment status for ozone, PM-2.5, PM-10, and CO. Only LA/LB are in “severe” or “serious” non-attainment status for any of these criteria pollutants, and of the other ports, only NY, Philadelphia, Chester, and Baltimore are in non-attainment for more than one criteria pollutant. Of the 24 ports, 12 are in attainment for all criteria pollutants; 6 of the 24 ports are in non-attainment only for ozone. Clearly, ozone is the most common non-attainment pollutant. Over 50% of the US population lives in ozone non-attainment areas (BNSF, based on EPA AIRS database). Only LA/LB are non-attainment for CO; all 21 ports are in attainment for SO₂ and lead.

Not surprisingly, the three largest container ports are also the areas of greatest air quality problems. This is of course due to the size of the cities as well as the amount of freight. Section 3.4.2 briefly examined the freight contribution to total emissions in these regions.

Note that attainment status for criteria pollutants does not necessarily reflect overall air quality. For example, although Houston is non-attainment for only one criteria pollutant (ozone), it is considered to have significant air quality problems, due in part to industrial pollutants. Also, no standards currently exist for one of the pollutants considered most harmful – ultrafine PM.

Table 20: Largest US Container Ports: Volume, Growth, 2006 Attainment Status (MARAD, EPA)

Port	2005 TEU	'00 – '05 CAGR ³	Attainment Status			
			8-Hour Ozone	PM- 2.5	PM-10	CO
Los Angeles, CA	4,914,811	8.8%	Severe 17	No	Serious	Serious
Long Beach, CA	4,412,302	6.6%	Severe 17	No	Serious	Serious
New York, NY	3,416,622	9.2%	Moderate	No ³	Moderate	OK
Charleston, SC	1,521,601	4.1%	OK	OK	OK	OK
Savannah, GA	1,490,663	15.7%	OK	OK	OK	OK
Oakland, CA	1,378,403	6.9%	Marginal	OK	OK	OK
Seattle, WA	1,342,368	6.9%	OK	OK	OK	OK
Norfolk, VA	1,324,507	9.3%	Marginal	OK	OK	OK
Houston, TX	1,250,213	11.3%	Moderate ¹	OK ¹	OK ¹	OK ¹
Tacoma, WA	1,160,047	12.4%	OK	OK	OK	OK
Miami, FL	778,437	2.6%	OK	OK	OK	OK
Port Everglades, FL	586,818	6.0%	OK	OK	OK	OK
Baltimore, MD	381,984	6.7%	Moderate	No	OK	OK
San Juan, PR	214,067	7.1%	OK	OK	OK	OK
Gulfport, MS	185,873	3.6% ²	OK	OK	OK	OK

Table 20 Continued

New Orleans, LA	181,414	-4.6% ²	OK	OK	OK	OK
Wilmington, DE	159,557	13.9%	Moderate	OK	OK	OK
W. Palm Beach, FL	157,394	5.1%	OK	OK	OK	OK
Philadelphia, PA	155,051	3.6%	Moderate	No ³	OK	OK
Jacksonville, FL	147,237	5.9%	OK	OK	OK	OK
Boston, MA	130,547	12.2%	Moderate	OK	OK	OK
Portland, OR	121,623	-10.5%	OK	OK	OK	OK
Newport News, VA	103,803	7.1%	Marginal	OK	OK	OK
Wilmington, NC	102,078	7.2%	OK	OK	OK	OK
Chester, PA	101,210	14.4%	Moderate	No	OK	OK

Notes:

1. Houston has other air quality issues related to industrial pollutants.
2. Volume and growth rates for Gulfport and New Orleans were affected by Hurricane Katrina.
3. New York and Philadelphia became non-attainment for PM-2.5 based on the lower limits established in September 2006.

3.4.4.2 Air Quality at Other Large Ports*

(* ports which are large in tonnage but not large in container volumes)

The table below lists the largest ports in the US based on total tonnage (import and export for all cargo types) in 2005. Ports listed under “Largest US Container Ports” have been omitted from this list. With the exception of Morgan City, Louisiana and Ashtabula/Conneaut, Ohio, only ports with over 25 million tons in 2005 are listed. Morgan City and Ashtabula/Conneaut are shown because of their exceptionally high growth rate from 2000 to 2005 at 22.5% compound annual growth rate (CAGR) for Morgan City and 48.5% CAGR for Ashtabula/Conneaut.

Many of these largest ports are in attainment for all pollutants shown, and all are in attainment for the other criteria pollutants (CO, SO_x, lead). It is noteworthy that with the exception of Perth Amboy, Morgan City, and Ashtabula/Conneaut, all these large ports showed little or negative tonnage growth from 2000 to 2005.

Table 21: Largest Other Ports (High Tonnage, not TEU): Volume, Growth, Attainment Status (MARAD, EPA)

Port	2005 Metric Tons	'00 – '05 CAGR ¹	Attainment Status			
			8-Hour Ozone	PM-2.5	PM-10	CO
Gramercy, LA	61,529,699	-2.5%	OK	OK	OK	OK
Corpus Christi, TX	49,801,218	-3.8%	OK	OK	OK	OK
Beaumont, TX	39,888,757	-1.7%	Marginal	OK	OK	OK
Texas City, TX	31,023,857	-1.0%	Moderate	OK	OK	OK
Lake Charles, LA	28,801,355	-0.6%	OK	OK	OK	OK
Mobile, AL	28,437,754	0.9%	OK	OK	OK	OK
Portland, ME	26,115,902	-1.0%	Marginal	OK	OK	OK
Perth Amboy, NJ	25,969,571	∞ ²	Moderate	OK	Moderate	OK
Port Arthur, TX	25,520,109	-2.3%	Marginal	OK	OK	OK
Morgan City, LA	9,640,459	22.5%	OK	OK	OK	OK
Ashtabula/Conneaut, OH	7,676,754	48.5%				

Notes:

1. 2005 volume for some gulf ports were affected by weather/damage.
2. Perth Amboy, NJ went from 0 tons in 2003 to 5M tons in 2004 and 25M tons in 2005.

3.4.4.3 Air Quality at Border Crossings

The following table lists the three busiest truck crossings between the US and Canada and the three busiest truck crossings between the US and Mexico (based on 2004 data). This list of

busiest truck crossing includes the two busiest rail crossings between the US and Mexico (Laredo and El Paso) and three of the five busiest rail crossings between the US and Canada (Port Huron, Detroit, and Buffalo-Niagara). Port Huron is the highest volume rail crossing on either border.

Two of the three largest border crossings between the US and Canada are non-attainment for both ozone and PM-2.5; all three are non-attainment for ozone. All three are in attainment for the other criteria pollutants (PM-10, CO, SO₂, lead). Of the three busiest border crossings between the US and Mexico, only Otay Mesa is non-attainment for ozone, and only El Paso is non-attainment for PM-10. These three areas are in attainment for all other criteria pollutants.

Table 22: Largest Border Truck & Railcar Crossings: Volume, Attainment Status (BTS)

Location	2004 Crossings		Attainment Status			
	Truck	Railcar	8-Hour Ozone	PM-2.5	PM-10	CO
Canadian Border						
Detroit, MI	1,701,452	234,823	Marginal	No	OK	OK
Buffalo-Niagara, NY	1,175,254	153,665	Subpart 1	OK	OK	OK
Port Huron, MI	945,962	474,175	Marginal	No	OK	OK
Total US-Canada	6,882,466	1,950,909				
Mexican Border						
Laredo, TX	1,391,850	317,061	OK	OK	OK	OK
Otay-Mesa, CA	726,164		Subpart 1	OK	OK	OK
El Paso, TX	719,545	110,992	OK	OK	Moderate	OK
Total US-Mexico	4,503,688	675,305				

3.4.4.4 Air Quality at Inland Freight Hubs

Two areas are examined: Chicago, a major rail hub, and San Bernardino, also known as the “Inland Empire”. The Inland Empire is a major hub for trucking, distribution centers and transloading facilities. Industrial development in the inland empire has been rapid, increasing by 18,000 acres in the last 10 years, and forecast to grow another 1,000 acres per year. The table below shows attainment status for criteria pollutants in these areas.

Table 23: Attainment Status at Inland Freight Hubs

Hub Location	Attainment Status			
	Ozone	PM-2.5	PM-10	CO
Chicago, IL	Moderate	No	OK	OK
San Bernardino, CA	Moderate	OK	Moderate	OK

3.4.4.5 Freight Contributions to Emissions at Gateways

Previous sections have examined freight emissions on a national and regional basis, and air quality at freight gateways. This section examines the relationship between freight emissions and air quality at major gateways. For the non-attainment pollutants at these gateways, how much of the total emissions of those pollutants are from freight?

The table below shows total freight contributions to NO_x and PM-10 for six areas, along with attainment data for NO₂, ozone, PM-10, and PM-2.5. Freight contribution to ozone cannot be directly measured, since ozone is formed as a by-product of other pollutants (principally

NOx and volatile organic compounds). Data on freight contribution to PM-2.5 emissions were not available.

This data shows that total freight contribution to these pollutants varies significantly by area. Freight NOx emissions range from below 30% to almost 40% of all sources. Freight PM-10 emissions vary from approximately 22% to 47% of all mobile sources. The entire U.S. is now in attainment for NO2, but many areas are non-attainment for ozone, of which NOx is an important precursor. As can be seen in the table, non-attainment is a more common problem for PM-2.5 than for PM-10, particularly since the standards for PM-2.5 recently became more stringent.

Table 24: Regional NOx and PM-10 Emissions and Attainment Status (ICF, EPA)

Region	Ozone Attainment Status	NO2 Attainment Status	Freight NOx Emissions		PM-2.5 Attainment Status	PM-10 Attainment Status	Freight PM-10 Emissions	
			% of Mobile Sources	% of All Sources			% of Mobile Sources	% of All Sources
Chicago	Moderate	OK	50.6%	34.1%	No	OK	39.9%	5.8%
Dallas	Moderate	OK	40.5%	34.9%	OK	OK	22.3%	1.0%
Detroit	Marginal	OK	51.2%	30.8%	No	OK	41.5%	2.2%
Houston	Moderate	OK	52.1%	28.9%	OK	OK	47.2%	1.7%
LA	Severe 17	OK	43.4%	39.1%	No	Serious	26.9%	1.8%

The tables below show modal (truck, rail, and marine) freight contributions to NOx and PM for the six areas. This shows that freight modal contributions to these pollutants vary significantly by mode and by area. Examining regional variations in modal contribution, rail contributions to total freight emissions range from 2% in Detroit to 19% in Chicago. Marine emission contributions range from 0% in Detroit and Dallas to 17% in Houston. In all areas, trucking is the largest contributor to freight emissions, ranging from a low of 79% in Houston to a high of 97% in Detroit. Clearly, trucking emissions are an important area for emission reduction programs. Fortunately, EPA tailpipe standards will cause a dramatic decrease in trucking emissions, which will be covered in sections 3.5.2 and 3.6.

Table 25: Regional NOx Emissions by Mode (ICF)

Region	Trucking	Rail	Marine	Air
Baltimore	83%	8%	9%	0.1%
Chicago	79%	19%	2%	0.4%
Dallas-Ft. Worth	93%	7%	0%	0.3%
Detroit	97%	2%	0%	0%
Houston	77%	6%	17%	0.1%
Los Angeles	78%	8%	14%	0.5%

Table 26: Regional PM-10 Emissions by Mode (ICF)

Region	Trucking	Rail	Marine	Air
Baltimore	74%	7%	19%	0.1%
Chicago	73%	22%	5%	0.3%
Dallas-Ft. Worth	88%	11%	0%	0.4%
Detroit	96%	2%	1%	0.1%
Houston	54%	6%	40%	0.1%
Los Angeles	54%	8%	37%	0.3%

The significance of these variations is that the effectiveness of any given mitigation measure will vary greatly between regions. Not only are there variations across modes (e.g. rail emissions are a much larger percentage of total freight emissions in Baltimore than in Detroit), but also within modes. For example, containerships contribute a much larger percentage of marine emissions in Los Angeles than in Houston. Therefore, measures targeting containership emissions are more helpful in Los Angeles than in Houston. These examples are given to emphasize that which is already clear: strategies to address air quality problems must be tailored to the region.

3.5 Regulatory Background

3.5.1 National Ambient Air Quality Standards

The National Ambient Air Quality Standards (NAAQS) were established by the Clean Air Act. There have been revisions to the NAAQS, including a reduction in September 2006 of the 24-hour standard for PM-2.5 from 65 $\mu\text{g}/\text{m}^3$ to 35 $\mu\text{g}/\text{m}^3$. A summary of current standards is given below. In order to achieve the NAAQS, states are required to produce State Implementation Plans (SIPs). These SIPs evaluate sources of emissions and outline each state's plan for achieving the standards.

Table 27: Summary of National Ambient Air Quality Standards

Pollutant	National Standard	Averaging Time
Ozone	0.08 ppm	8-hour
PM-2.5	15.0 $\mu\text{g}/\text{m}^3$	Annual
	35 $\mu\text{g}/\text{m}^3$	24-hour
PM-10	150 $\mu\text{g}/\text{m}^3$	24-hour
CO	9 ppm	8-hour
	35 ppm	1-hour
NO ₂	0.053 ppm	Annual
SO _x	0.03 ppm	Annual
	0.14 ppm	24-hour
Lead	1.5 $\mu\text{g}/\text{m}^3$	Quarterly

3.5.2 Emission (Tailpipe) Standards

The first standards for tailpipe emissions in the US went into effect in 1975, and covered CO, volatile organic compounds (VOC), and NO_x for cars and light duty trucks. The first standards for heavy duty trucks went into effect in 1984. Emission standards for freight locomotives were significantly later, going into effect in 2000, although they govern emissions from locomotives produced as early as 1973 when they are remanufactured. Emission standards for commercial marine diesels went into effect beginning in 2004.

The standards have become increasingly stringent, as concern over air quality has grown, and as the technology to enable reductions has become available. The following tables show the emission standards over time for heavy duty trucks, locomotives, Category 2 marine (such as tugs), and Category 3 marine (OGVs). A subset of EU standards for trucks is shown for comparison, and is quite similar to US standards. The purpose of this data is to show the large improvements (i.e. tightening) of emission standards over time. The only exception to the tightening of standards is for carbon monoxide (CO). New standards for heavy duty diesel engines do not regulate carbon monoxide (CO) because diesel engines are inherently low in CO emissions, and the goal of increased fuel efficiency leads to decreased CO emissions.

When comparing emission standards between modes, it should be noted that truck and locomotive standards are in grams per brake-horsepower-hour, whereas marine emission standards are in grams per kilowatt-hour. One kilowatt-hour equals 1.33 brake-horsepower-hours. Differences in standards between modes are discussed in the next section.

The decreases in emissions are quite dramatic, especially for the 2007/2010 (phased) truck requirements, decreasing from approximately 2 grams/bhp-hr for NO_x to 0.2 grams/bhp-hr,

and PM also decreasing by 90%. The reductions in PM necessitate the use diesel particulate filters (DPF), which require periodic maintenance. There has been concern that these new engines will be less fuel efficient, but it is believed that the reduction will be minimal. When the 2007/2010 requirements are fully phased in, it is anticipated that selective catalytic reduction (SCR) may be required to meet the standards. SCR requires a reductant, typically urea, which adds to the operating expense, since the reductant is consumed. These new requirements also add to the initial cost of the engine.

Substantial differences exist between regulation of emissions from stationary sources and mobile sources. For stationary source in non-attainment areas, no increases in emissions are allowed without changes at other stationary sources to offset the new emissions. For mobile sources, limiting new emissions is more difficult. (We don't say "you can't drive any more trucks into this city because we already have too much pollution"). Further, stationary sources are limited in emissions of not only criteria pollutants, but also for 188 Hazardous Air Pollutants.

Unlike stationary sources, mobile sources are generally not regulated for individual "hazardous air pollutants" (HAPs). Exceptions to this generalization include benzene and diesel particulate matter. HAPs are substances which are known or believed to cause adverse effects to human health. There are 188 substances included. Steps which have been taken to reduce mobile source air toxics include limits on gasoline volatility and limits on diesel fuel sulfur content.

Table 28: U.S. Heavy Duty Truck Emission Standards (EPA, grams/bhp-hour)

Year	NOx	PM	HC	CO
1984	10.7	unregulated	1.3	15.5
1988	10.7	0.6	1.3	15.5
1990	6	0.6	1.3	15.5
1991	5	0.25	1.3	15.5
1994	5	.10	1.3	15.5
1998	4	.10	1.3	15.5
2004	2.0	.10	0.5	unregulated
2007/10 ¹	0.2	.01	0.14	unregulated

Notes:

1. Standards are phased requirements from 2007 to 2010

Table 29: European Union Heavy Duty Truck Emission Standards for NOx and PM, grams/bhp-hour

Year	NOx	PM
1992	6.0	0.27
1996	5.3	0.19
1998	5.3	0.11
2000	3.8	0.075
2005	2.6	0.015
2008	1.5	0.015

Source: Dieselnet, converted from grams/kW-hour

Table 30: U.S. Locomotive Emission Standards, Line Haul Duty Cycle (EPA, grams/bhp-hour)

Tier	Year	NOx	HC	PM	CO
Unregulated	< 2000	13.0 ¹	0.48 ¹	0.32 ¹	1.28 ¹
0 ²	2000	9.5	1.0	0.60	5.0
1	2002	7.4	0.55	0.45	2.2
2	2005	5.5	0.30	0.20	1.5
3 ³	2012	5.5	0.30	0.10	unregulated
4 ³	2015	1.3	0.14	0.03	unregulated

Notes:

1. Unregulated emission factors are estimated in-use emission rates from 1997.
2. Tier 0 standards, effective in 2000, apply to locomotives manufactured in 1973 and later when remanufactured.
3. Tier 3 and tier 4 are proposed standards.

Table 31: EPA Category 1 & 2 Marine Emission Standards, grams/Kw-Hr

Tier	Year	NOx¹	PM¹
1	2004	9.8 – 17.0	unregulated
2	2004 - 2007	7.2 – 11.0 ¹	0.20 – 0.50
3	2009 – 2014	3.5 – 8.2 ¹	0.08 – 0.20
4	2014 – 2017	1.3	0.03 – 0.19

Notes:

1. A range of values is given based on differing standards according to engine size.
2. Values for Tier 2 and Tier 3 NOx are for the total of NOx + HC.

Table 32: EPA/IMO Emission Standards for Category 3 Marine Engines, grams/Kw-Hr

Standard	Year	NOx	PM
IMO	2005 ¹	17.0 ³	unregulated
EPA Tier 1	2004 ²	17.0 ³	unregulated
EPA Tier 2 ⁴	Tbd	Tbd	Tbd

Source: EPA and IMO

Notes:

1. IMO MARPOL Annex VI emission requirements apply to vessels constructed 2000 or later, but went into effect in 2005.
2. EPA requirements apply to marine engines manufactured in 2004 or later, but apply only to U.S. flagged vessels.
3. Only values for the slow speed diesels used on ocean going vessels (OGV) are shown.
4. EPA set a target of 2007 for Tier 2 requirements for Category 3 marine engines (OGV).

3.5.3 Comparison of Emission Standards across Modes

The table below compares emission factors for NOx and PM for heavy duty diesel trucks, locomotives, non-road diesels (such as those used in cargo handling equipment), category 1 and 2 marine vessels, and ocean going vessels (category 3). Factors for category 3 marine diesels are shown only for the slow speed diesels which are common in containerships. The factors shown are based on the latest in-force standards, including 2007/2010 truck requirements, even though the standard has not been fully phased-in. Proposed standards are not shown, nor are standards which have been adopted but are not yet in force, such as tier 4 requirements for non-road engines. All factors have been converted to grams per brake-horsepower-hour.

As is evident from the table, there are large variations in emission factors between modes. Current regulations for new heavy duty trucks require much lower emissions per unit of energy output than other modes. Regulations for non-road engines are next most stringent, and OGVs are the least regulated. EPA has regulatory authority only over US flagged vessels, although EPA is considering applying standards to international vessels when in US waters. It should be rail and marine have much higher fuel efficiency than trucking, resulting in net emissions per ton-mile which are low, despite the relatively higher emission factors. This is particularly true for CO₂ emissions which are directly related to fuel efficiency.

The difference in emission standards between modes, along with varying fleet turnover rates between modes, will cause a shift in the proportion of total emissions from each mode. Due to the projected rapid decreases in trucking emissions (based on 2007/2010 requirements), marine and locomotive emissions are projected to become a larger percentage of total freight emissions. This projection, coupled with the higher emissions per unit energy of locomotives and especially of marine vessels, explains the level of attention that is being focused on marine and rail emissions. See section 3.6.2 for these projections.

Table 33: Comparison of NOx and PM Emission Factors across Modes, per bhp-hr

Mode	NOx¹	PM¹
Truck	0.2	0.01
Non-Road ²	2.25	0.11
Locomotive	5.5	0.2
Category 1, 2 Marine	5.4 – 8.25	0.15 – 0.38
Category 3 Marine ³	12.75	unregulated

Source: EPA, IMO

Notes:

1. All factors are given in grams per brake-horsepower-hour. Factors for marine engines were converted from the grams per kilowatt-hour listed in the standards.
2. Non-road emission factors vary with engine size. Factors listed are for engines between 175 and 600 horsepower.
3. Emission factors for category 3 marine are for slow speed diesels operating below 130 rpm.

3.5.4 Fuel Requirements

Fuel requirements serve as both a direct means to emission reductions, and also to enable the use of some emission reduction technologies. For example, the primary motivation of the recent ultra low sulfur diesel (ULSD) highway fuel requirement was to enable the use of after-treatment devices (DPFs) on 2007 model year trucks. However, the lower sulfur content of the fuel also reduces PM emissions on older vehicles, with the reduction estimated at approximately 10%. The reduction of emissions by using lower sulfur fuel applies not only to trucks, but for all modes. For example, lower sulfur fuel is required for marine vessels in SECAs (Baltic Sea, North Sea, and English Channel) to reduce emissions. Also, one ocean carrier made a voluntary commitment to use lower sulfur fuel when operating near California ports.

The table below summarizes past and present requirements for sulfur content of diesel fuel for trucks, locomotives, non-road equipment, and category 1, 2, and 3 marine engines. California has different fuel requirements which are not discussed here. The data shows the large reduction over time in sulfur content for all modes except category 3 marine, and the large variation in requirements between modes.

Just as emission factors are more stringent for highway diesels than for other modes, fuel requirements for trucks are also more stringent than for other modes. The differences are dramatic, with highway fuel (ULSD) at 15 parts per million (ppm), compared to bunker fuel used in ocean going vessels at 27,000 ppm, nearly 2,000 times higher. Even the lower sulfur fuel used in SECAs contains up to 15,000 ppm, or up to 1,000 times higher than the fuel used in trucks.

Not only does the sulfur content vary, but there are large differences in price between marine bunker fuel (used in category 3 vessels) and the fuels used in other modes. The large price difference and the dramatically higher sulfur content of bunker fuel are due to the type of crude oil used. “Sweet” crude is low in sulfur content, but “sour” crude, used for bunker fuel for ocean going vessels, has a much higher sulfur content. For all modes except ocean going vessels, reducing sulfur content has resulted (or is expected to result) in only a small increase in price. For ocean going vessels, reducing sulfur results in a large price increase, since it requires either using “sweet” crude or an expensive process called “cracking” to remove sulfur.

Before the sulfur content of fuel was regulated, fuel for all modes except ocean going vessels contained 3,400 ppm sulfur. Highway fuel was reduced to 500 ppm sulfur in 1993, and then to 15 ppm (ULSD) in 2006. Fuel for locomotives, non-road engines, and category 1 and 2 marine engines all contain 500 ppm, and will be reduced to 15 ppm between 2010 and 2012. Except for the recent designations by IMO of SECAs, fuel used by ocean going vessels has

been virtually unregulated. The standard for bunker fuel, at 45,000 ppm, is often viewed as a non-standard, since it is higher than nearly all available fuel. The high sulfur content of bunker fuel leads to high SO_x emissions of ocean going vessels, and also to higher emissions of PM. Due to increasing pressure to reduce emissions of ocean going vessels, some organizations, including those representing shipping interests, have proposed eliminating use of bunker fuels. Such a change would significantly reduce emissions. However, the increase in cost would be large, and the availability of adequate supplies of low sulfur fuel is in question.

Table 34: Comparison of Diesel Sulfur Content by Mode

Mode	Unregulated Sulfur Content	Current Sulfur Requirements And Date	2010/2012 Sulfur Content	Approximate Cost⁴
Heavy Duty Truck	~3,400 (<1993)	15 (2006)	15	\$3.00/gal
Non-Road	~3,400 (<2007)	500 (2007)	15	\$2.95/gal
Locomotive, Marine Cat 1,2	~3,400 (<2007)	500 (2007)	15	
Marine Cat 3	27,000 ²	45,000 (2005)	No change	\$1.20/gal
Cat 3 SECA ¹	15,000	15,000	planned	\$2.30/gal

Notes:

1. Sulfur Emission Control Area (current SECAs are Black Sea, North Sea)
2. As an alternative to using fuel with $\leq 15,000$ ppm sulfur in SECAs, ships can use other methods which limit SO_x emissions to the same level.
3. Worldwide average sulfur content of bunker fuel is 27,000 ppm.
4. Costs are from October 2007.

3.5.5 Freight Growth at Gateways in Non-Attainment Areas

Many of the high growth gateways are in non-attainment areas for one or more pollutants. Los Angeles, Long Beach, New York, Oakland, Norfolk, Houston, and Baltimore are all in non-attainment for one or more pollutants. With the exception of Los Angeles where TEU growth was slower, these ports experienced annual growth rates ranging from 10% to 19% between 2003 and 2005. These high growth rates have the potential for emission increases to exceed the reductions from newer vehicles and various mitigation strategies. As more ports develop annual emissions inventories, it will be feasible to track progress of port impacts to air quality in each area.

3.5.6 Effects of Concentration on Emissions

Although overall freight emissions in the US are projected to decrease substantially (see section 3.6.1), emissions at some gateways will decrease more slowly, or even increase for some pollutants. This will occur at gateways with high growth rates and high activity of ocean going vessels, since these vessels have less stringent emission requirements and slower fleet turnover than trucks. Concentration of freight at key gateways, and decreases in overall/national emissions indicate that freight-related air quality problems are increasingly focused at these freight gateways.

3.6 Trends in Freight-Related Air Quality

Preceding sections have focused on past and current freight volume, emissions, air quality at major gateways, and standards for air quality, emissions, and fuel. This section examines trends in freight emissions based upon the following factors which will change over time, or which have already changed but their effects have not yet been fully felt:

- Projection of future trade growth.
- Current and pending fuel requirements.
- Current and pending emission standards.
- Fleet turnover.

3.6.1 Current and Projected Freight Emissions

Due to stricter emission standards and fuel requirements for trucks, locomotives, non-road equipment and marine vessels, total freight emission in the US are projected to decrease despite strong growth in freight volumes. Total freight NO_x emissions are projected to decrease 63% from 2002 to 2020 (ICF). PM-10 emissions are projected decrease 50% from 2002 to 2020 (ICF). However, these decreases are far from uniform across all modes. Truck emissions are projected to decrease the most, and vessel emissions the least. See tables below. Despite the significant increase in air freight NO_x emissions, they are projected to be only 0.6% of the total freight NO_x emissions in 2020. These projections do not consider the proposed Tier 3 & Tier 4 locomotive standards or the proposed standards for Category 1 & 2 marine engines.

Table 35: Freight NOx Emission Projections (ICF)

Year	Truck	Rail	Marine	Air	Total
2002	baseline				
2010	-42%	-34%	-2%	+22%	-34%
2020	-82%	-43%	-7%	+51%	-63%

Table 36: Freight PM-10 Emission Projections (ICF)

Year	Truck	Rail	Marine	Air	Total
2002	baseline				
2010	-46%	-26%	-2%	-3%	-33%
2020	-71%	-39%	0%	-10%	-50%

The reason for the smaller decrease of marine and locomotive emissions is the less stringent emission regulations (especially for ocean going vessels) and slower fleet turnover compared to trucks. Marine vessels and locomotives have a service life of 30-40 years or more. Rates of emission improvements from locomotives are helped somewhat by the requirement that older locomotives meet emission standards at the time of remanufacture. For older marine engines, IMO emission requirements apply only when the engine undergoes a “major conversion”, such as replacement with a new engine or increase in rated power. Also, even when vessels are required to meet the IMO emission requirements, the standards are far less stringent than other modes, at 17 grams/Kw-Hr¹ for NOx, and no requirement for PM.

1. IMO requirement for slow speed marine diesels.

3.6.2 Effects of Varying Regulations and Rates of Improvement

As a result of the more stringent emission regulations for trucks and the relatively faster fleet turnover compared to vessel and locomotive, trucks are projected to become a smaller portion of total freight emission, and vessels a much larger portion. The following tables give data for modal shares of freight emissions in 2002, and projections for 2010 and 2020.

Table 37: Freight PM-10 Emissions, Percentages by Mode

Year	Truck	Rail	Marine	Air
2002	64.7%	11.5%	23.7%	0.2%
2010	52.6%	12.7%	34.5%	0.2%
2020	37.7%	14.1%	47.9%	0.3%

Source: ICF, 2005, based on EPA National Emission Inventory

Table 38: Freight NOx Emissions, Percentages by Mode

Year	Truck	Rail	Marine	Air
2002	66.8%	15.1%	17.9%	0.1%
2010	58.4%	15.0%	26.3%	0.3%
2020	31.6%	23.2%	44.7%	0.6%

Source: ICF, 2005, based on EPA National Emission Inventory

Areas with lower vessel and locomotive activity will experience larger percentage decreases in freight emissions. This means that areas whose freight activity is primarily trucking, such as at major truck border crossings or trucking hubs, will see significant progress toward air quality goals from the freight sector. On the other hand, areas with high vessel and

locomotive activity will experience smaller improvements in air quality from freight activity. Depending upon the growth rate and mix of modes, some areas may experience increases in freight emissions. As a result, areas with high vessel and/or locomotive activity may be more likely to enact local regulations in order to achieve air quality goals.

Another result of the variation in regulation between modes is that the difference in “cleanness” between modes is changing. To date, marine and rail transportation have been considered less harmful to air quality than trucking. However, with the new 2007/2010 emission standards for trucks, comparison between rail, marine, and truck emissions of NO_x and PM are less clear. While energy efficiency is much higher for rail and marine than for truck, the per-energy emission factors for truck are much lower than for rail or marine. If emission requirements for vessels and locomotives ever reach par with trucks (on an emissions per energy output basis), water and rail transport would again have much lower emissions per ton-mile than trucks, due to their inherently greater fuel efficiency.

An example of the projected increasing share of total freight emissions coming from marine emissions is seen in the projections for the lower Fraser Valley in Vancouver, BC. By 2015, marine vessels are expected to become the largest contributor to smog forming pollutants (primarily NO_x and VOC), not only largest among freight sources, but among all sources. See the graph below.

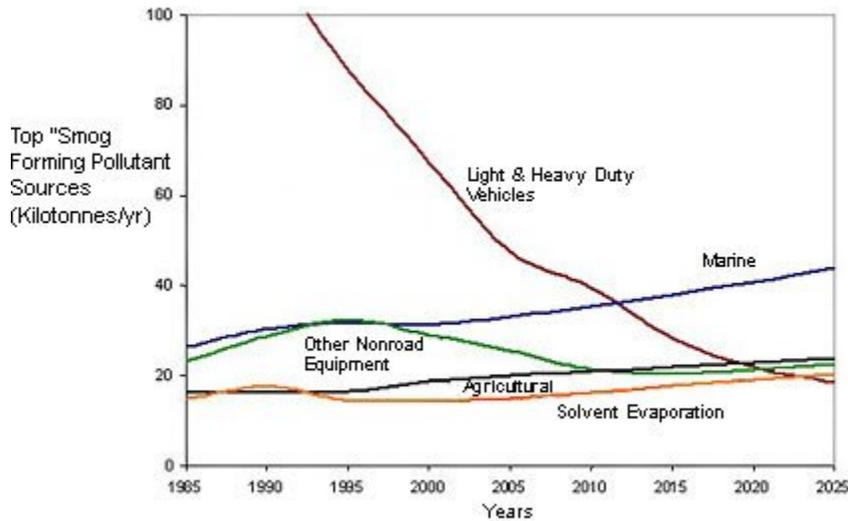


Figure 1: Forecast and Back Cast of the 2000 Emission Inventory for the Lower Fraser Valley Airshed 1985 – 2025 (Greater Vancouver Regional District)

3.6.3 Role of Idling and Congestion

3.6.3.1 Trucking

Truck idling has been estimated to use roughly 5% of heavy truck fuel (Gaines, 2004), resulting in significant contribution to trucking emissions. While efforts are made to reduce overnight idling through truck stop electrification and APUs (auxiliary power units), increasing congestion on highways will offset some of the gains. With constant lane-miles and growing VMT for both for trucks and passenger vehicles, congestion and idling will increase, unless there is widespread implementation of demand management, such as congestion pricing. As congestion increases and as emissions per energy output decrease, idling emission reductions will become a more important element of trucking emissions mitigation. Logistics practices to avoid congestion, maximize load factors, and use the most efficient routing will grow in importance as means of reducing emissions.

3.6.3.2 Rail

Idling is estimated to account for 6% to 10% of locomotive fuel consumption (Gaines, 2004), with resulting emissions. Idling accounts for a substantial fraction of operating hours, not only for switchers, but also for line haul locomotives. Also, rail traffic has been increasing while trackage has been decreasing, and average speeds have been declining (AASHTO Freight Rail Bottom Line Report). Rail delays in Chicago sometimes result in containers being trucked between rail yards. Reliability of rail transportation can be a hindrance in attracting shippers to use rail. The decreasing average speed and trucking between yards suggest that railroad idling emissions may be a growing percentage of total rail emissions, and an increasingly important candidate for mitigation measures.

3.6.4 Summary of Freight Trends and Effects on Air Quality

The following table provides a brief summary of some of the major trends in goods movement in the US, along with their expected or potential effects on air quality.

Table 39: Summary of Freight Trends and Air Quality Effects

Trends	Environmental Implications
<p>1. Rapid growth of container trade, particularly with China.</p>	<ul style="list-style-type: none"> ○ Increasing emissions from vessels, concentrated at gateway ports. EPA regulations apply only to U.S. flagged vessels built after 2004. IMO Annex VI only regulates SO_x (minimally) & NO_x, and only affects vessels manufactured or undergoing conversion after 2000. ○ Emissions at gateways from dray and line haul trucks, locomotives, and port equipment not decreasing as quickly as would otherwise occur from stricter EPA regulations. US heavy duty vehicle NO_x emissions projected to decrease 83% from 2002 to 2020 (ICF); California statewide truck NO_x emissions projected to decrease 61% from 2001 to 2020 even with additional measures, and California truck NO_x emissions from international goods movement projected to decrease only 33% (CARB Emission Reduction Plan 3/21/06).

Table 39 (continued)

<p>2. Volume of container trade expected to triple in next 15-20 years, but emission standards becoming more stringent.</p>	<p>U.S. freight transportation emissions projected to decrease from 2002 to 2020 (ICF, does not include marine terminal cargo handling): NOx: -63% PM-10: -50%</p>
<p>3. Increases in freight transportation costs.</p>	<p>May promote continued growth of inter-modal.</p>
<p>4. Voluntary use of lower sulfur fuel by Maersk at California ports.</p>	<p>Lower emissions.</p>
<p>5. West coast port congestion, growth of east coast and gulf coast DCs. Rapid growth of east and gulf coast container ports at Norfolk, Savannah, and Houston.</p>	<p>Possible more rapid increase in emissions at east coast and gulf coast ports. This is most significant for susceptible non-attainment port cities.</p>
<p>6. Increasing vessel size.</p>	<ul style="list-style-type: none"> ○ Continuing concentration of traffic and impacts at deepest-draft ports. ○ Increased need for dredging. ○ Higher peak demands and congestion, potential increase in idling/emissions. ○ Increased dwell time.
<p>7. Transloading</p>	<ul style="list-style-type: none"> ○ More efficient goods transport due to higher capacity of 53' over 40'. ○ Drayage often involves older, higher emission trucks.

Table 39 (continued)

<p>8. Concentration of container volumes at load center ports. (85% in 2005 vs. 80% in 1997)</p>	<p>This concentrates emissions in those areas. Areas with less rapid growth will see most sources of emissions decreasing due to improving technology, EPA regulations, and fleet turnover.</p>
<p>9. Rising land prices.</p>	<p>Transloading facilities moving further inland, with potential that truck miles and emissions will increase (due to higher per-ton emissions of dray truck with 40' container than line haul truck and 53' trailer).</p>
<p>10. Increasing vessels sizes and depth requirements, coupled with very long lead time for dredging projects</p>	<p>Continuing concentration of volume and environmental impacts at ports with deeper harbors.</p>
<p>11. Increasing highway congestion</p>	<p>Increasing emissions from idling.</p>
<p>12. Some shippers taking cost-savings measures which have negative environmental implications. Refuse to use on-dock rail & ACTA.</p>	<p>Increases trucking/emissions. Potential effects on capacity.</p>
<p>13. TEU/call up from 2845 in '00 to 3423 in '05</p>	<p>Longer dwell time, greater hoteling emissions per call, but potential decrease in emissions per TEU.</p>
<p>14. All water to east coast gaining market share over west coast + intermodal.</p>	<p>Reduces growth of emissions over land, increases emissions over ocean.</p>

Table 39 (continued)

15. Shippers becoming more environmentally-conscious, even if only for appearance (initially).	Contributes to finding more efficient ways to move freight, reducing costs and emissions.
16. Increasing length of intermodal trains, increasing use of double-stack.	Increases capacity. Reduces emissions.
17. Tightening emission standards, but increasing volume, slow turnover. (Minimal improvements to standards for ocean going vessels.)	AQ improvements in areas where volume not increasing rapidly (applies primarily to areas which do not have high activity of ocean going vessels).
18. Rapid increase in empties. Empty containers sometimes are not picked up promptly, and get moved to off-dock location.	Long-term storage of empties can result in additional moves, causing increased emissions from cargo handling equipment.
19. Requirements for environmental impacts/mitigation vary by port	Less difficult to increase capacity in areas with less severe air quality problems.
20. Rapidly escalating dredging costs due to environmental requirements.	Increasing advantage to ports with naturally deep harbors. May contribute to need for higher productivity. May contribute to concentration of volume at load centers.
21. Storm water requirements limit ability to develop available land at port.	Contributes to need for higher productivity.

Table 39 (continued)

<p>22. Increased border security</p>	<p>Additional delay/idling at border crossings. New requirements are burdensome for LTL at border crossings. Rail increasing faster than truck for NAFTA container trade.</p>
<p>23. Increasing rail congestion: reduces reliability; speed decreasing. (Cite stats from AASHTO report. Check) Difficult to obtain/permit land for expanding yards.</p>	<p>Potential hindrance to growth of intermodal. Trucking between rail yards in Chicago. Higher emissions.</p>
<p>24. Night operation at ports</p>	<p>Reduces congestion at gate and on highways, reducing emissions. Moves emissions to off-peak times which is a benefit. Noise/light pollution issues increase.</p>
<p>25. Higher fuel prices</p>	<p>Contributes to attractiveness of intermodal, reducing emissions. Encourages efficiency in logistics, such as higher load factors. Efficient logistics reduce emissions. Encourages adoption of technologies to reduce fuel consumption, which also reduces emissions, e.g. APUs.</p>
<p>26. Economics of Asia –Atlantic – east coast route improving.</p>	<p>Potential air quality benefits due to shorter land segment (population center is closer to east coast than west coast).</p>

Table 39 (continued)

27. High growth in international air cargo	Highest emissions per ton-mile for some pollutants. Night-time flights, common for freight, have much greater GHG effects than daytime flights.
28. West coast port costs increasing: Pierpass, Auxiliary Engine Rule	Potential diversion of volume to other ports.
29. Rapid growth of international freight is occurring in some non-attainment areas.	Freight growth offsets gains from emission standards and fleet turnover, making it more difficult to achieve air quality standards.
30. Increasing size of distribution centers.	Concentration of environmental impacts near those large distribution centers and the ports serving them.

4.0 IMPLICATIONS AND PRINCIPLES FOR BEST PRACTICES

Based on the trends in freight volumes and current and projected emissions, a number of principles can be derived to guide the evaluation of practices for mitigation. These principles are grouped into the categories of economics, geography, idling and congestion, modal aspects, and land use. These principles follow logically from the data presented in earlier sections of the report, and are described below.

Economics

- Particular focus should be placed on measures which are cost and environmentally effective at gateways, hubs, and urban areas, where freight-related air quality problems are concentrated. Focusing on the most cost effective measures allows the funds available for mitigation to result in the greatest overall benefit, and places the least economic burden on public and private entities.
- Cost effectiveness of mitigation strategies varies dramatically between measures and between modes. Cost per ton of emission reductions is lower for some mobile sources, particularly ocean-going vessels, than for many stationary sources (Entec). Therefore, cost effectiveness should be compared across measures, across modes, and across sectors (e.g. transportation and power generation).
- Wherever possible, internalize the external costs of freight transportation, which causes market forces to shift freight to more environmentally-friendly modes, times, routes, and practices.

Geography

- Some areas are more susceptible to air quality problems than others due to natural topography and atmospheric conditions, and will therefore require more stringent

emission standards and/or more effective practices to achieve and maintain ambient air quality standards.

- For areas with rapid freight growth and/or non-attainment status (or at risk of non-attainment), it may be necessary to accelerate freight emission decreases by accelerating fleet turnover, or other mitigation strategies such as retrofit/re-power. These strategies may not be justifiable on a national scale, since many areas are in attainment, and overall US freight emissions are decreasing.
- Mitigation measures vary in effectiveness and cost-effectiveness by area. For example, hybrid vehicles such as delivery trucks have the greatest potential to reduce emissions in congested areas. While hybrids offer significant emission benefits in most driving conditions, they offer large reductions under congested conditions. These are also the conditions with the largest percentage fuel economy increases, thereby making hybrids more cost-effective under congested conditions.
- Due to variation in emission contribution by mode and activity, solutions must be tailored to the region. For example, requiring containerships to use AMP may be effective in Los Angeles, but would be less effective in Houston where containerships are a much smaller portion of freight emissions.
- Due to the influence of vessel emissions in coastal waters on air quality over populated areas, measures beyond those for ocean transport are needed in some regions. Examples include Sulfur Emission Control Areas, California's Auxiliary Engine Rule and upcoming Main Engine Rule, and vessel speed reduction.
- In order to provide the greatest flexibility, lowest regulatory costs, and lowest overall cost of emission reductions, limiting total emissions from all modes/activities at ports should be considered, rather than a set of specific requirements. This approach would allow ports to determine the most cost-effective methods across all modes and activities. Although such an approach has the potential to create requirements which vary greatly between ports and are thereby increase complexity for compliance,

coordination between ports and carriers could minimize variation in the requirements imposed on carriers.

- Measure should be sought which offer the greatest environmental and health benefits at the lowest costs. Note that the largest emission reductions do not always equate to the largest health benefits. For most emissions (NO_x, PM, other criteria pollutants), large environmental benefits in sparsely populated areas which already have acceptable air quality are less valuable (in terms of health benefits) than equal or even smaller environmental benefits which occur in densely populated areas with poor air quality. This is not true for GHG emissions, since the location of GHG reductions is not important.
- Concentration of freight at key gateways, and decreases in overall/national emissions indicate that freight-related air quality problems are increasingly focused at these gateways. Due to the concentration and to variations in sources and emissions “capacity”, local measures and/or voluntary/incentive-based programs are important.
- AQ problems are heightened in urban areas, where smaller (i.e. smaller than class 8) trucks constitute a larger percentage of truck traffic and emissions than on a national basis. Although the focus on class 8 trucks for reducing trucking emissions is appropriate given their large contribution to national trucking emissions, smaller trucks should not be overlooked, particularly when considering measures to improve AQ in urban areas. Some approaches to reducing trucking emissions are currently more feasible for smaller trucks. One example is hybrid-electric vehicles, where most of the development and potential uses are for smaller trucks used for local delivery. Given the substantial contributions of smaller trucks to urban trucking emissions, and the tendency of freight efficiency initiatives to be among the most cost effective measures, the field of city logistics is an important area for addressing both urban freight emissions and congestion.

Idling and Congestion

- As VMT growth continues to outpace lane-mile growth, increasing congestion will cause truck idling emissions to increase and to become a growing percentage of total truck emissions. Although idling presently comprises a small percentage of trucking emissions, practices which reduce idling emissions will become increasingly important.

Land use

- Land use planning and transportation planning can be utilized to minimize the air quality and health effects of freight. Fifty years hence, a large percentage of the then total development has not yet been built. Therefore, it is productive to search for land use & transportation planning solutions to achieve long-term environmental and health benefits. The following are examples of land use planning and transportation planning approaches.
- Freight transportation through residential and densely populated areas should be minimized to reduce exposure to freight emissions. Freight facilities such as warehouses can be located near freeway interchanges to reduce truck VMT.
- Locate DCs in areas with rail access to reduce drayage. The “shuttle train” to move containers from the ports to the Inland Empire in southern California was deemed economically infeasible, but similar approaches may be viable in other areas.
- Locating industry near rail access provides environmental benefits. Some regional air quality agencies have taken steps to encourage this, and rail carriers also promote this approach.
- Locating transloading facilities close to a port helps to reduce emissions. 53’ highway trailers have 60-70% more capacity than 40’ ocean containers. Therefore,

locating transload facilities close to the port will reduce truck VMT. It would also help address the shortage of drayage drivers.

- To the extent possible, development of freight facilities should be encouraged in areas which are in attainment and which are not congested.

Modal Aspects

- Since heavy duty truck and rail emissions are decreasing, reducing marine emissions of is of increasing importance to overall mitigation efforts.
- Due to the longer lifecycle of locomotives and marine vessels, retrofit/re-power measures may be more productive for these modes than for trucking.
- Rail transport provides lower fuel consumption than trucking and lower GHG emissions, and in some cases for regulated pollutants. Continued growth of intermodal traffic despite significant rate increases demonstrates a willingness among shippers to pay higher rail rates. However, concerns about velocity and reliability limit the growth of intermodal traffic. Rail investments which improve velocity & reliability may be beneficial both to railroad profitability and to societal welfare, even if they result in further increases in rates. Research in this area could be fruitful.

Summary of Principles for Best Practice Evaluation

Since overall US freight emissions are projected to decrease, (2) areas vary in emissions contributions of different freight modes, and (3) many areas are and will remain in attainment, “best” practices are those which:

- Provide both environmental and economic benefits
- Address short- and medium-term air quality problems
- Address the specific problems of non-attainment areas

- Encourage the movement of freight through attainment areas, and in a manner which reduces VMT
- Reduce idling and congestion
- Assist the attractiveness of modes with low impacts to air quality
- Provide not only the most cost-effective environmental benefits, but the most cost-effective health benefits, considering both the current air quality and population density of the given area
- Don't place unnecessary economic burden the entire U.S. by imposing costly requirements on a national scale
- Yet, despite the above, avoid creating a patchwork of federal/state/local regulations.

5.0 CONCLUSION

Summary of Trends

International container trade has been growing at seven percent per year, doubling volumes in ten years, thereby putting tremendous pressure on ports, connecting infrastructure, and border crossings. This rapid growth causes congestion, delays, and emissions increases for some modes. In addition to the overall growth rates, the higher growth rate of imports over exports and the high growth rates with key trading partners such as China and India have the potential to accelerate growth. Doubling of container volumes could occur even more quickly.

While container trade has been growing rapidly, it has also been concentrating at the largest ports, with over 85% of ocean container volumes now handled by the largest ten U.S. ports. This concentration is driven by the economics of warehouse consolidation, larger vessels sizes, and the large local markets near major ports. Many of these large ports where container volumes are concentrating are already congested, and are non-attainment for one or more criteria pollutants. Because of the economic factors driving the concentration of container volumes, concentration can be expected to continue, thereby necessitating solutions compatible with the concentration. The combined challenges of congestion, capacity, and emissions are likely to require both emission reduction measures and demand management, as is already occurring at southern California ports.

A number of factors create challenges to handling the rapid increase in container trade. One of the most significant is the growing size of containerships, with orders for vessels over 10,000 TEU becoming commonplace. These larger vessels create higher peak demands at ports, connecting highways, and rail facilities, and substantially increase the capital costs required to accommodate them. At the same time that capital costs are increasing, the useful lifespan of some port structures is decreasing. These costs make it difficult for all but the

largest ports to make the required investments, thereby contributing to further concentration of container volumes at the largest ports. Also, these larger vessels require deeper channels and harbors, adding to pressure on the already constrained resources for dredging.

Intermodal offers benefits for both emissions and highway congestion, and volumes have been growing rapidly. Nevertheless, significant challenges remain to intermodal growth. Improvements are needed to velocity and reliability, which are hindered by bottlenecks, congestion, and delays. Environmental requirements and environmentally-based opposition make capacity expansions difficult and slow.

Although air cargo and emissions are projected to grow, these emissions will remain a small fraction of total freight emissions. For CO₂ emissions, air cargo contributions are more significant, due to the higher fuel consumption per ton-mile compared to other modes. The importance of these GHG emissions are increased by air cargo's use of night flights when condensation trails have a greater GHG warming effect. This aspect of air cargo emissions may warrant further study.

While ocean, rail, air cargo, and trucking are experiencing strong growth, use of inland waterborne transportation has declined substantially. This decline is a concern, particularly as highway congestion increases, and funds for highway maintenance and expansion are in short supply.

Summary of Air Quality Impacts

Despite the rapid growth of container transportation, long term freight emissions are expected to decline between 2002 and 2020. However, these decreases are far from uniform across modes. Due to the wide variation in emission and fuel standards between modes, the makeup of freight emissions will change markedly. The dominant source of national freight emissions is expected to change from trucking to marine by 2020. The proposed locomotive

and marine rule would affect the relative modal contributions, but the lack of effective regulation of ocean going vessels indicates that marine vessels may indeed become the dominant source of freight emissions on a national basis.

The greatest remaining challenges for reducing freight emissions, at least those challenges which are currently identified, are emissions of ocean going vessels and ultrafine particulate emissions from trucks. For ocean going vessels, stricter emission standards are needed to check the growth of emissions. Engine manufacturers are capable of large emissions reductions, and many carriers are amenable to more stringent requirements as long as they are uniformly applied.

Due to the limited dispersion of ultrafine particulate matter, these emissions are less of a concern for ocean going vessels than for trucking or locomotives. Although it may be years before the health effects and mitigation options for ultrafine particulate matter emissions are fully understood, it is not too early to begin taking action based on what is already known. Solutions are available through exhaust after-treatment and land use planning.

Numerous agencies are involved in monitoring and regulating freight emissions. These include local, state, federal, and international agencies, with varying approaches, sometimes lacking coordination. This leads to frustration among carriers and ports seeking to reduce emissions and to comply with applicable regulations. There is a clear need for greater cooperation among these various agencies.

Final Thoughts

Despite the rapid increase of U.S. international container trade and the resulting domestic freight movements, substantial reductions in overall freight emissions are projected and are already underway for some modes, based on increasingly stringent emission standards. Large reductions are projected for trucking, and significant decreases are also forecast for rail emissions, although not as large as for trucking. In order to continue and enhance the

emission reductions projected for rail, the proposed Tier 3 and Tier 4 standards are needed. These standards are attainable with currently available technology, although some of this technology is still in the pilot stage. Even at Tier 4 standards which are proposed for 2015, emission factors for locomotives would be less stringent than the 2007/2010 requirements for trucks.

In order to prevent marine emissions from becoming the dominant source of freight emissions, to help achieve ambient air quality standards and their attendant health benefits, and to prevent environmentally-based opposition from hindering efficient goods movement, reductions in emissions from ocean going vessels are urgently needed. While numerous approaches are available to reduce emissions, more stringent emission standards are essential. Without uniform (worldwide) emission standards, a variety of state or local regulations will ensue, as is already occurring in California, resulting in complexity and increased costs for ocean carriers as they seek to comply with regulations which vary by port. This is the reason for the World Shipping Council's request to the International Maritime Organization to quickly implement new standards.

Large reductions in emissions of ocean going vessels are achievable with available technology, both for new vessels and for existing vessels through retrofits. Opportunities for retrofits are frequent, as engines are rebuilt every few years. Reductions can be achieved without the large costs associated with major changes to fuel such as the proposed elimination of bunker fuel. It is vital to pursue the means which are most cost-effective and most acceptable to all stakeholders. As listed in the appendix, there are a wide variety of measures available to reduce emissions, some of which also generate cost reductions.

Effective communication of these approaches will be an important element in their adoption and in the overall success in reducing emissions. Cost-effective solutions must be actively promoted to achieve the needed reductions, and to preclude the adoption of undesirable

approaches. These reductions are necessary to protect the health of people living near freight gateways and hubs, and to protect trade growth and economic development.

6.0 RECOMMENDATIONS FOR FURTHER RESEARCH

While the research for this paper answered a number of questions about the relationship between freight trends and air quality, a number of other questions were identified, some of which may be ground for future research. These topics span the fields of transportation engineering and planning, environmental and atmospheric science, and economics. Although nearly all of the topics listed are inter-disciplinary, they have been categorized according to their primary focus. The questions which appear more promising or more important candidates for research are listed near the top of each category.

Environmental Engineering

1. What are the dispersion characteristics of NO_x, PM, and SO_x emissions, especially for marine vessels? The quantity of emissions which reach populated areas is a key factor in cost-effectiveness calculations for mitigation measures. Measures can't be accurately compared without adequate understanding and agreement on this subject.
2. Ultrafine PM emissions are believed to be among the most hazardous pollutants, and are effectively unregulated. Ambient levels are dramatically higher near major roadways than at other locations. Research is needed to develop a more complete understanding of health effects, safe ambient levels, relative contributions of heavy truck and automobile traffic, appropriate emission standards, control technologies, and policies.
3. CO₂ emissions from air cargo may be more significant than generally believed. This is due to air cargo's greater use of night flights, and the greater greenhouse gas warming effect of night flights compared to daytime flights. Quantification of air cargo's effective contribution to greenhouse gas warming would be valuable.

General Engineering (multi-disciplinary)

4. Perform detailed evaluation and web publishing of the most promising practices among the list of over 250 identified.
5. Can a methodology for evaluation of best practices be found which are acceptable to key players, such as EPA, IMO, AAPA, IAPH, Ecoports, and BIMCO for the marine sector? A widely accepted methodology for evaluation could promote greater adoption of these practices.
6. Low emission zones (LEZs) focus emission reductions where the need is greatest, without imposing unnecessary costs in other areas. Investigation of specific approaches is recommended.

Transportation Planning

7. What is the economic feasibility of single container maglev rail transport of containers from a port to an inland logistics park? Promoters of the technology claim it can be cost-effective, but an independent evaluation may be useful, particularly where new ports are being planned.
8. What are the primary causes of decreases to rail trackage (not counting multiple tracks but only total distance covered)? What are the effects on air quality, land use (location of industries), and truck traffic?
9. Is overall ocean borne freight concentrating at key ports, or is the phenomenon of container concentration rather a part of a broader trend of port specialization? If so, what are the implications for freight efficiency, transportation infrastructure, land use (i.e. industry location), and environmental impacts? Among the U.S. ports with the highest growth of container volumes, many show low growth in tonnage. Ports with the highest growth in total tonnage have low growth rates of container volumes. This

may be due to break-bulk cargoes shifting to other ports – there is evidence of this occurring.

10. Is the volume of goods trans-shipped to or from the U.S. through Canada and Mexico growing appreciably? Limited data from 1993 to 1996 showed some growth through Canada, and several Canadian ports are actively promoting service to U.S. cities, sometimes offering competitive or faster transit times than through U.S. ports. What are the current trends in this regard, and what are the implications for U.S. transportation infrastructure?
11. What are the primary causes and effects of the significantly decreasing modal share of inland waterborne transport? What are the effects on infrastructure, environment, land use, industry, and agriculture? What would be the costs and benefits of improvements to the inland waterway system, including infrastructure, air quality, and congestion costs (lost time) in each mode?
12. What are the transportation infrastructure, efficiency, environmental, and economic benefits of a widespread shift from 40 foot ocean containers to 53 foot ocean containers? Should DOT and MARAD take steps to encourage such a shift?
13. Growth patterns in container trade should be monitored, paying particular attention to differences in import and export growth and differences among trading nations. This will enable more accurate predictions of growth and the effects on transportation infrastructure. There is potential for growth to accelerate.

Marine Terminal Engineering and Operations Planning

14. The rapid growth and concentration of container volumes and the limited availability of land for expansion will require increased port and terminal productivity. This increased productivity will require large capital expenditures. Will adequate funding be available to support the required investments in productivity at both publicly and

- privately run ports/terminals? The ability to make these large investments is likely to determine the long-term growth or stagnation of individual ports.
15. Short sea shipping, with environmental and highway congestion benefits, is growing rapidly in some areas of the world, but is very limited in most areas of the U.S. Are there marine terminal designs or other approaches which lower the container handling costs of short sea shipping? These handling costs are an impediment to greater use of short sea shipping and its attendant benefits to highway congestion. Costs of added handling were estimated at a minimum of \$500 per transshipped container in late 1990s (Alderton).
 16. Can an economic case be made for ocean carriers to offer lower speed container services at a lower cost (not to replace current high speed services)? Large reductions in fuel consumption and emissions could be realized.

Economic

17. What are the historic and current rates firms use to calculate inventory holding costs, and how have trends in these rates affected freight transportation mode choice and the overall transportation network?
18. What are the effects on modal share and network coverage (e.g. trackage) of the public vs. private ownership of highway and rail infrastructure?
19. What would be the effect on sourcing decisions of charging full social costs for freight transportation? For example, are freight-imposed costs such as customs and security covered fully by user fees? If not, is the public, in effect, being taxed to facilitate the outsourcing of jobs? If so, how large is this effect?

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APPENDIX

Appendix – List of Candidate Best Practices

Candidate Best Practices - OUTLINE

- I. Practices for Rail
 - A. Best Practice – Emissions and Cost Reductions
 - 1. Technology
 - 2. IT
 - 3. Operations
 - 4. Institutional
 - 5. Infrastructure
 - B. Practices with Air Quality Benefits, Economic Benefits not determined
 - 1. Technology
 - 2. IT
 - 3. Operations
 - 4. Institutional
 - 5. Infrastructure
 - C. Practices with Air Quality Benefits, Increased Costs
 - D. Pilot and Concept Practices

- II. Practices for Trucking
 - A. Best Practice – Emissions and Cost Reductions
 - 1. Technology
 - 2. IT
 - 3. Operations
 - 4. Institutional
 - 5. Infrastructure
 - B. Practices with Air Quality Benefits, Economic Benefits not determined
 - 1. Technology

2. IT
3. Operations
4. Institutional
5. Infrastructure

C. Practices with Air Quality Benefits, Increased Costs

D. Pilot and Concept Practices

III. Practices for Ocean

A. Best Practice – Emissions and Cost Reductions

1. Technology
2. IT
3. Operations
4. Institutional
5. Infrastructure

B. Practices with Air Quality Benefits, Economic Benefits not determined

1. Technology
2. IT
3. Operations
4. Institutional
5. Infrastructure

C. Practices with Air Quality Benefits, Increased Costs

D. Pilot and Concept Practices

IV. Practices for Inland Waterborne

A. Best Practice – Emissions and Cost Reductions

1. Technology
2. IT
3. Operations
4. Institutional

- 5. Infrastructure
- B. Practices with Air Quality Benefits, Economic Benefits not determined
 - 1. Technology
 - 2. IT
 - 3. Operations
 - 4. Institutional
 - 5. Infrastructure
- C. Practices with Air Quality Benefits, Increased Costs
- D. Pilot and Concept Practices

- V. Practices for Port/Terminal
 - A. Best Practice – Emissions and Cost Reductions
 - 1. Technology
 - 2. IT
 - 3. Operations
 - 4. Institutional
 - 5. Infrastructure
 - B. Practices with Air Quality Benefits, Economic Benefits not determined
 - 1. Technology
 - 2. IT
 - 3. Operations
 - 4. Institutional
 - 5. Infrastructure
 - C. Practices with Air Quality Benefits, Increased Costs
 - D. Pilot and Concept Practices

- VI. Practices for All Modes
 - A. Best Practice – Emissions and Cost Reductions
 - 1. Technology

2. IT
3. Operations
4. Institutional
5. Infrastructure

B. Practices with Air Quality Benefits, Economic Benefits not determined

1. Technology
2. IT
3. Operations
4. Institutional
5. Infrastructure

C. Practices with Air Quality Benefits, Increased Costs

D. Pilot and Concept Practices

VII. Unlikely Candidates for “Best” Practice

I. Practices for Rail

I. A. Best Practices - Emission and Cost Reductions

I A.1 Technology - Rail

1. Hybrid switchers
 - a) Description: Diesel/electric hybrids are available for both yard switchers and road switchers. Most North American Class 1 railroads are using or have ordered hybrid switchers.
 - b) Source:
<http://www.ffca2006.com/documents/presentations/rail/Karen%20Dzienkowski.pdf>
 - c) Why: Fuel savings and emission reductions are large. Relatively short payback period.
2. Gen-set switchers
 - a) Description: Gen-set switchers use 2-3 truck type engines instead of a single large locomotive engine. This allows the emission improvements which have been developed in the high volume truck market to be used in switch locomotives. Not suitable for line haul applications.
 - b) Source:
<http://www.ffca2006.com/documents/presentations/rail/Mike%20Iden.pdf>
<http://www.progressiverailroading.com/freightnews/article.asp?id=9981>
<http://www.progressiverailroading.com/freightnews/article.asp?id=9398>
 - c) Why: Emissions reduced ~80%, fuel consumption reduced up to 35%. Quieter operation than conventional switchers.
3. Electric parking space (on-board & off-board components)

- a) Description: An electric parking space, or plug-in unit, allows locomotives to be shut down instead of idling. Heats coolant and oil, and charges batteries.
 - b) Source: <http://epa.gov/smartway/idlingtechnologies.htm#loco-stat-epsds>
 - c) Why: Reduces idling, fuel and lube oil consumption, engine wear, and emissions.
4. Automatic shut down and start up
- a) Description: The engine is automatically shut down after a specified time idling. Water temperature, brake pressure, and other parameters are monitored to determine if/when the engine needs to be (automatically) restarted.
 - b) Source: <http://www.northeastdiesel.org/pdf/locomotive-report-june-2006.pdf>
 - c) Why: Reduces idling, fuel and lube oil consumption, engine wear, and emissions.
5. Auxiliary Power Unit (APU)
- a) Description: An APU uses a small engine to heat the cab, coolant, and oil, and charge batteries, allowing the main engine to be shut down.
 - b) Source: <http://www.northeastdiesel.org/pdf/locomotive-report-june-2006.pdf>
<http://www.ecotranstechnologies.com/company.asp>
 - c) Why: Reduces idling, fuel and lube oil consumption, engine wear, and emissions.
6. Diesel driven heating system
- a) Description: Allows locomotives to be shut down instead of idling, by heating the cab, coolant, and oil, and charging batteries.
 - b) Source: <http://www.transportation.anl.gov/pdfs/RR/290.pdf>
7. Rail: Lightweight materials, e.g. aluminum and composite
- a) Description: Lightweight materials such as aluminum or composites are used in some rail cars.
 - b) Source:
http://www.findarticles.com/p/articles/mi_m1215/is_n8_v198/ai_19697468

http://www.findarticles.com/p/articles/mi_m1215/is_n11_v196/ai_17720556

<http://www.progressiverailroading.com/freightnews/article.asp?id=9947>

c) Why: Increased capacity and reduced fuel consumption and emissions.

I A.2 IT - Rail

8. Locomotive Engineer Assist Display and Event Recorder (LEADER®).

a) Description: “Developed by New York Air Brake, the system provides locomotive engineers real-time information on operating conditions. An on-board computer calculates and displays optimum speed based on topography, track curvature, train length and weight, and other operating conditions.... NS officials plan to make LEADER an integral part of Optimized Train Control (OTC), a positive train-control system designed to combine data communications, positioning systems and onboard computers tied to a train’s braking systems to automatically enforce speed and operating limits. The Class I currently is testing OTC, which NS, Lockheed Martin and GE developed earlier this year.”

b) Source: PROGRESSIVE RAILROADING.COM, 12/6/2005 Technology

c) Why: 8% fuel efficiency gain (source – AAR, Railroad Fuel Efficiency and the Environment), reduced emissions.)

9. Environmental Management Systems

a) Why: Some of the benefits of developing an EMS include:

-Improved community relations and public image

-Cost savings

-Improved internal communication

-Increased competitiveness and market opportunities

Source:

(<http://www.northeastdiesel.org/pdf/locomotive-report-june-2006.pdf>)

I A.3 Operations - Rail

10. Engineer training and incentives
 - a) Description: Engineer training and incentives, such as the Fuel Masters program, rewards engineers with highest fuel efficiency.
 - b) Source: http://www.uprr.com/newsinfo/2006/fuelmasters_facts.shtml
 - c) Why: Fuel consumption reduced and average of 5%. Reduced emissions. Potential increase in safety and velocity. No capital costs.
11. Engine shutdown policy with or without wireless monitoring where APUs not used
 - a) Description: If not equipped with an automatic shut down and start up system, railroad policies provide guidelines for manually shutting down.
 - b) Source: http://www.arb.ca.gov/railyard/rrsubmittal/up_idling_training.pdf, slide 5
 - c) Why: Reduces idling, fuel and lube oil consumption, engine wear, and emissions.
12. Double stack intermodal (standard practice, but included in this list because the environmental benefits should be considered when considering costs of projects required to enable double stack, such as raising tunnel clearances)
 - a) Description: Double stack increases the capacity and fuel efficiency of intermodal trains.
 - b) Source: “The External Costs of Freight Transportation”, Forkenbrock, http://www.marshall.edu/cber/research/TRP99-24_FR.pdf
 - c) Why: Fuel consumption reduced 10%. Reduced emissions.

I A.4 Institutional - Rail

13. Co-Production

- a) Description: Rail co-production involves multiple carriers sharing track, sometimes turning two two-way sections of track into a one-way loop.
- b) Source: <http://www.aapa-ports.org/files/SeminarPresentations/06%5FHNE%5FFranczak.pdf>
- c) Why: Increased capacity and velocity. Reduced congestion/idling/emissions (check)

14. Land use near major roads and freight facilities

- a) Description: Avoid new development of sensitive land uses near major roads and freight facilities
- b) Source: CARB Land Use Handbook
- c) Why: Reduces exposure to emissions, especially ultrafine PM, levels of which drop off sharply as distance from the source increases. Ultrafine emissions are difficult to control, due in part to some of the formation occurring after leaving the tailpipe.

I A.5 Infrastructure - Rail

15. Double & triple tracking

- a) Description: Increases capacity of rail network, enabling growth of intermodal. Reduced congestion.
- b) Why: Reduced fuel consumption and emissions (see “Eliminate rail bottlenecks” for more information on emissions)

I. B. Air Quality Benefits, Economic Benefits not determined

I. B.1 Technology - Rail

16. Horizontal transfer of containers from rail to truck

- a) Description: Using special equipment on trucks and rail cars, containers can be transferred between truck and rail without any special equipment at the terminal.
- b) Source: <http://www.eutp.org/download/itip/D1/Annex1.pdf>
- c) Why: Potential to increase use of intermodal, thereby reducing emissions.

17. Electric locomotives (line haul or yard)

- a) Description: Electric locomotives are used for both passenger and freight in some countries/locations, such as in Germany, Switzerland, and Japan. Electric locomotives over 8,000 HP are available in Europe.
- b) Source: <http://www.worldcargonews.com/htm/n20050609.495466.htm>
<http://www.transportation.siemens.com/ts/en/pub/products/lm/services/platforms/eurosprinter.htm>
<http://www.jrtr.net/jrtr26/pdf/photo.pdf>
LOS ANGELES BASIN RAILWAY ELECTRIFICATION STUDY (library for hard copy)
- c) Why: Reduced emissions, reduced maintenance, reduced fuel cost (depending upon prices of diesel and electricity). Increased acceleration with potential for increased capacity and velocity (check). Some claim that higher property taxes on electrified railways are an important factor working against electrification of railroads in the US.
(http://www.lightrailnow.org/features/f_lrt_2005-02.htm)

18. Flow through filter

- a) Description: “Flow-through filters can employ catalyzed metal wire mesh structures or tortuous flow, metal foil-based substrates with sintered metal sheets to reduce diesel PM.”
- b) Source: <https://vault.swri.edu/Retrofit/Documents/TechPaper.pdf>
<http://www.northeastdiesel.org/pdf/2006-0425--BostonHarborScopingFinalReport.pdf>
- c) Why: A catalyzed wire mesh filter removes more particulate matter than a DOC, and does not require as high exhaust temperature as a DPF. PM reductions are 30-75%. Less likely to become clogged than a DPF.

19. ULSD prior to EPA requirement in 2012

- a) The current EPA requirement for locomotives diesel fuel is 500 ppm sulfur, compared to ULSD sulfur content of 15 ppm. The CARB 2005 MOU with UP and BNSF calls for 80% of California intrastate locomotive fuel to be ULSD.
- b) Source:
http://www.uprr.com/newsinfo/releases/environment/2007/0117_oxicat.shtml
<http://www.fhwa.dot.gov/environment/freightaq/chapter4.htm>
- c) Why: ULSD reduces SOx and PM (4% to 20%) emissions, difference in unit fuel price is relatively small (i.e. difference is much smaller than the difference between bunker and marine distillate fuels).

20. Natural gas dual fuel locomotive

- a) Description: Locomotives can be converted to run on a combination of natural gas and diesel.
- b) Source: <http://www.energyconversions.com/locoemis.htm>
http://www.rrdc.com/article_07_2006_fcga_dual_fuel_pwr_RGI.pdf
- c) Why: Reduced NOx, SOx, and GHG. Increased HC and CO, slight increase in PM. No significant fuel penalty. BNSF says less efficient than some new diesel locomotives (check)

<http://www.maritimeairforum.org/workshop/BNSF%20Presentation%20%5BRead-Only%5D.pdf>, slide 15

21. LNG locomotive

a) Description: Locomotives can be converted to run on LNG

b) Source:

<http://www.westcoastdiesel.org/files/grants/LNG%20Locomotive%20Project%20Fact%20Sheet.pdf>

<http://scitation.aip.org/getabs/servlet/GetabsServlet?prog=normal&id=JETPEZ000122000001000130000001&idtype=cvips&gifs=yes>

c) Why: Reduced NO_x and PM.

22. Steerable trucks

a) Description: Steerable trucks for reduce friction by improving alignment.

b) Source:

http://www.arena.org/eseries/scriptcontent/custom/e_arena/library/1999_Conference_Proceedings/00056.pdf

c) Why: Reduced friction, fuel consumption, wear, and emissions. Allows increased speed on curves. With steerable trucks, there is no need for wheel/rail lubrication.

23. Low torque bearings

a) Description: Low torque bearings reduce torque by 38%.

b) Source:

<http://www.businessroundtable.org/pdf/ClimateRESOLVE/Sept29/Stehly.BNSF.pdf>, slide 12

c) Why: Reduced fuel consumption (1-3%) and reduced emissions.

24. Locomotives with wheel flange lubricators and top of rail lubrication

a) Description: Lubricating wheels/rails reduces friction.

b) Source: Railroad Fuel Efficiency and the Environment, Fronczak/AAR presentation

c) Why: Fuel consumption reduced 1-5%. Reduced emissions.

25. Gage face lubrication for curves

- a) Description: Gage face lubrication reduces friction on curves.
- b) Source:
http://www.railcan.ca/site_rgi2006/documents/2006_05_01_RobertFronczak_AAR.pdf
- c) Why: Reduced fuel consumption and emissions.

I B.2 IT - Rail

26. Truck performance detectors

- a) Description: Equipment can automatically measure and report the performance of wheel sets for locomotives and rail cars.
- b) Source: <http://www.railsciences.com/atpms.html>
- c) Why: Prevents derailment, identifies maintenance needs. (check effects on fuel consumption and emissions)

27. Wireless feedback to crews

- a) Description: Automatic wireless feedback to crews on train handling assists crews in efficient operation.
- b) Source:
http://www.railcan.ca/site_rgi2006/documents/2006_05_01_RobertFronczak_AAR.pdf
- c) Why: Improves efficiency and reduces emissions.

28. Positive train control

- a) Description: Positive train control systems provide communications and control to enhance the safety and efficiency of train operations.
- b) Source:
<http://www.stsc.hill.af.mil/Crosstalk/2007/01/0701AlfordDitmeyer.html>
<http://www.fra.dot.gov/us/content/784>

- c) Why: Reduced fuel consumption and emissions. Increased capacity and safety.
29. Consist Manager™ (check cost effectiveness)
- a) Description: Consist Manager provides computerized control of the throttle settings for lead and trailing locomotives to obtain the highest overall fuel efficiency.
 - b) Source:
http://www.bnsf.com/employees/communications/bnsf_today/2006/01/2006-01-30-e.html
 - c) Why: Reduces fuel consumption by 1-3%. Reduced emissions.
30. Radiation portal monitor
- a) Description: Radiation detection can be performed while the vehicle is moving, allowing radiation security check without increasing idling/emissions.
 - b) Source:
http://www.cbp.gov/xp/cgov/border_security/port_activities/rad_portall.xml
31. VACIS gamma-ray inspection at rail border crossings
- a) Description: Allows inspection while train is moving at up to 8 mph,
 - b) Source: <http://www.saic.com/products/security/rr-vacis/>
 - c) Reduces idling and emissions compared to stationary inspection.
32. Rail: Weigh in Motion Scales
- a) Description: Rail cars are weighed as they pass over the scales at up to 10 mph.
 - b) Source:
<http://www.akrr.com/pdf/2007%20Weigh%20In%20Motion%20Scale.pdf>
 - c) Why: Reduces labor, increases safety. (Check on fuel/emissions reduction)
33. Yard automation
- a) Example: Formosa Plastics

b) Source:

<http://www.lib.ncsu.edu:2067/ehost/pdf?vid=3&hid=120&sid=4fa14b1c-b443-4934-8b5d-484e2eeb7fad%40sessionmgr102>

I. B3. Operations – Rail

34. Pacing (part of positive train control)

a) Description: Allow trains to run at less than maximum speed while still maintaining performance/schedule requirements. Lower speeds produce substantially lower aerodynamic drag.

b) Source: [http://links.jstor.org/sici?sici=0030-](http://links.jstor.org/sici?sici=0030-364X(199101%2F02)39%3A1%3C82%3AOPOTIF%3E2.0.CO%3B2-W#abstract)

[364X\(199101%2F02\)39%3A1%3C82%3AOPOTIF%3E2.0.CO%3B2-W#abstract](http://links.jstor.org/sici?sici=0030-364X(199101%2F02)39%3A1%3C82%3AOPOTIF%3E2.0.CO%3B2-W#abstract)

<http://www.businessroundtable.org/pdf/ClimateRESOLVE/Sept29/Stehly.BNSF.pdf>, slide 10

c) Why: Reduces fuel consumption and emissions.

35. Reserved capacity for freight rail to avoid conflicts w/ passenger trains, e.g. Trans European Freight Freeways (priority of freight vs. passenger may differ between US and Europe - check)

36. Improving intermodal loading configuration

a) Description: Arranging cars and reducing gaps reduces aerodynamic drag.

b) Source:

<http://cee.uiuc.edu/railroad/CEE/pdf/Lai%20&%20Barkan%202005.pdf>

c) Why: Fuel consumption can be reduced by up to 1 gallon per mile, and emissions are reduced.

37. Barge-rail, e.g. Carolinks

I. B.4 Institutional - Rail

38. Network-wide capacity analysis of intermodal
 - a) Source: <http://ec.europa.eu/transport/rail/research/doc/uic-ct-sum.pdf>
39. Industrial zoning along rail lines and inland waterways
40. Retire highest emitting locomotives
41. Preserve land for intermodal terminals and rail corridors
42. Idling restrictions for locomotives (bill 3502 [California? check])
43. Avoid “penalty” for voluntarily going beyond emission requirements; can preclude from obtaining government funding (comment came from Railroad Environmental Conference – Mel Burda/BNSF?)
44. Funding for RR research (most government funding for research has been on trucks)
45. Encourage re-use of brownfields
46. Non-monetary incentives, such as public recognition for emission reductions.
47. Promote/facilitate modal shift from truck to inland waterway or rail.

I. B.5 Infrastructure - Rail

48. Eliminate rail bottlenecks to assist mode-shift
 - a) Description: The typically lower velocity and reliability of rail (or the perception of it) limits growth of intermodal.
 - b) Source:
 - c) Why: Intermodal has emission benefits over pure trucking (emission benefits for CO₂; benefits for regulated emissions depends on various factors including age of the locomotives and trucks)
49. Trans European Networks (TENS): hub & spoke (check applicability to US)
50. Grade separations

- a) Description: Grade separations reduce delays, idling, and emissions.

I. C. Air Quality Benefits, Increased Costs - Rail

51. B20 biodiesel

- a) Description: Use biodiesel in locomotives.
- b) Source: <http://www.nrel.gov/docs/fy04osti/33436.pdf>
- c) Why: Reduced CO and net GHG emissions, but slight increase in NOx and no significant change in PM emissions.

52. Oxygenated diesel (ethanol diesel blend)

- a) Description: Diesel can be blended with ethanol to reduce emissions.
- b) Source: <http://www.transportation.anl.gov/pdfs/RR/261.pdf>
<http://www.fhwa.dot.gov/ENVIRONMENT/freightaq/chapter4.htm>
<http://www.ethanol-gec.org/winter99/win9913.htm>
<http://www.oxydiesel.com/oxyindex.html>
<http://www.transportation.anl.gov/pdfs/RR/261.pdf>
- c) Why: A study by Southwest Research Institute showed that a 15% ethanol blend reduced CO emissions by 27%, PM by 41%, and NOx by 5%. Does not require engine modifications. Reduction in fuel economy. Lower lubricity contributes to higher injector wear.

53. Regenerative braking

- a) Description: Trains obtain some of their braking by generating electricity from traction motors, but this energy is lost because it is dissipated as heat. The energy can be stored in batteries.
- b) (see presentation from RREC conference)
<http://www.northeastdiesel.org/pdf/locomotive-report-june-2006.pdf>
- c) (Check cost-effectiveness – unlikely – see presentation from RR Environmental Conference)

54. Accompanied Combined Transport

- a) Description: In some countries, freight trucks and their drivers travel by rail for part of the trip.
- b) Source: <http://www.ectri.org/liens/yrs05/Session%202ter/kutacek.pdf>
- c) Why: Study showed the costs of subsidized accompanied combined transport were higher than the benefits.

55. Emulsified diesel

- a) Description: Water can be emulsified in diesel fuel to reduce emissions. Additives are required to produce a stable mixture. This practice is most feasible for centrally fueled vehicles.
- b) Source: <http://www.westcoastdiesel.org/files/sector-locomotive/Emulsified%20Diesel%20for%20Locomotive%20Applications%200.pdf>
<http://www.lubrizol.com/PuriNOx/fueltechnology.asp>
- c) Why: 30% NO_x reduction, 50% PM reduction. Estimated cost ~\$0.25/gallon. Potential reduction in peak horsepower.

56. DPF (current practice in some instances in Europe, pilot in US)

- a) Description: Locomotives can be built new or retrofit with DPF. This is more feasible for switchers than for road locomotives, due to concerns about adequate space for the DPF in road locomotives. DPFs have been installed on over 80 locomotives in Europe, mostly on 2,000 HP locomotives, but also on one 3,600 HP locomotive. DPFs are being evaluated in California.
- b) Source: <http://www.meca.org/galleries/default-file/MECA%20locomotive%20and%20marine%20case%20study%20report%201006.pdf>
http://www.arb.ca.gov/railyard/rsubmittal/dpf_sum.pdf
<http://www.arb.ca.gov/railyard/ryagreement/071306iden.pdf>
- c) Why: Large reduction in PM emissions.

57. Rebuild Tier 0 and Tier 1 engines to Tier 2, or re-power (replace engine)

- a) Description: When locomotives manufactured between 1973 and 2001 are re-manufactured, they must meet EPA Tier 0 standards. When locomotives manufactured between 2002 and 2004 are re-manufactured, they must meet Tier 1 standards. Tier 2 standards apply to locomotives manufactured in 2005 or later. When Tier 0 and Tier 1 engines are re-manufactured, they can be rebuilt to Tier 2 standards.
- b) Source: <http://www.northeastdiesel.org/pdf/locomotive-report-june-2006.pdf>
- c) Why: Tier 2 emissions are more than 50% lower than Tier 0. Cost differential between rebuilding to Tier 0 or Tier 1 and rebuilding to Tier 2 is believed to be small (check; also check effect on operating costs)

I. D. Pilot and Concept Practices - Rail

58. Coal gasification and Fischer-Tropsch fuels

- a) Description:
- b) Source: <http://featured.matter-mag.com/2006/11/can-coal-clean-transportation-fuel.cfm> (look for another source)

59. Hybrid yard tractors

- a) Description: Hybrid yard tractors are being evaluated at the ports of LA/LB, but might also be used at rail yards (check). Different usage patterns (hours/year) may make the economics different for rail yards than for ports.
- b) Source:
- c) Why: Projected reduction at LA/LB of 93% for NO_x and PM. Reduction in fuel consumption and GHG, less noise than conventional units. Higher initial price, but lower operating expenses.

60. Fuel cell locomotives

- a) Description: There is long-term potential to use fuel cells for motive power, including locomotives. The US Army is developing a 120-ton, 1 megawatt fuel cell locomotive. For switchers, a hybrid (fuel cell + battery) would be more economical than exclusive fuel cell.
 - b) Source: http://www.fuelcellpropulsion.org/army_locomotive.htm
<http://www.ffca2006.com/documents/presentations/rail/Arnold%20Miller.pdf>
 - c) Why: Fuel cells have zero emissions and higher efficiency than internal combustion engines. (The higher efficiency results in large reductions in CO2 emissions. Check gases which various types of fuel cells emit.)
61. Reduce drag of empty coal cars
- a) Description: Fairings, foils, or baffles reduce aerodynamic drag of empty coal cars.
 - b) Source: Railroad and Locomotive Technology Roadmap
 - c) Why: Fuel consumption can be reduced by 5%. Emission reduction.
62. Maglev single container vehicles
63. Homogeneous Charge Compression Ignition (HCCI)
- a) Source: <http://www.transportation.anl.gov/pdfs/RR/261.pdf>
http://www.greencarcongress.com/2006/10/caterpillars_va.html
64. Variable Compression Ratio Engines
- a) Source: <http://www.transportation.anl.gov/pdfs/RR/261.pdf>
http://www.greencarcongress.com/2006/10/caterpillars_va.html
65. Non-Thermal Plasma Catalysts
66. DOC Retrofit
- a) Description: Locomotives can be retrofit with diesel oxidation catalyst, depending on space limitations. DOCs are one of the few effective means of reducing ultrafine PM emissions.
 - b) Source:
http://www.uprr.com/newsinfo/releases/environment/2007/0117_oxicat.shtml
<http://www.northeastdiesel.org/pdf/locomotive-report-june-2006.pdf>

<http://www.aqmd.gov/aqmp/07aqmp/draft/07aqmp.pdf>
(SCAQMD 2007 draft plan chap 11)

- c) Why: PM emissions can be reduced by 25-50%. A test of a UP locomotive using ULSD and a DOC showed a 50% reduction in PM, enabling a 17-year-old locomotive to meet Tier 2 requirements for PM.

67. Improved lubrication, friction modifiers

- a) Why: Fuel consumption reduced. Reduced emissions.

68. Machine vision gap analysis for intermodal trains

- a) Description: A machine vision system can monitor gaps in intermodal trains to assist terminal managers in improving loading patterns.

- b) Source:

<http://cee.uiuc.edu/railroad/CEE/pdf/Lai%20et%20al%202005%20IHHA33.pdf>

- c) Why: Reduced fuel consumption and emissions.

69. Advanced Locomotive Emission Control System (ALECS)

- a) Description: Stationary emission control (scrubber + SCR) reduces emissions while locomotives are in the service area.

- b) Source: <http://www.arb.ca.gov/railyard/ryagreement/071306placer.pdf>

- c) Why: SO_x, NO_x, and PM reduced by 95%-99%.

70. Remote sensing of high emitting locomotives (CARB MOU requires investigation of this approach); UP pilot program

71. DPF + SCR on head end (auxiliary) power

- a) Description: Head end units generate power for the entire train. (*Check applicability to freight locomotives – may be only passenger.*)

- b) Source: <http://www.arb.ca.gov/railyard/ryagreement/071306bogdanoff.pdf>

- c) Why: A pilot project on passenger locomotives anticipates a 90% reduction in NO_x and PM.

72. Supply Chain Coordination

- a) Description:

- b) Source: <http://www.aapa-ports.org/files/SeminarPresentations/06%5FHNE%5FFranczak.pdf>

73. Shuttle Train

- a) Description: A shuttle train could be used to move containers from ports to inland terminals. This approach was evaluated for moving containers from the ports of LA/LB to the inland empire, but found to not be economically feasible.
- b) Why: Reduced highway congestion and emissions.

74. Oxygen-enriched Combustion

- a) Source: <http://www.anl.gov/techtransfer/Awards/docs/clean-diesel.html>
<http://www.memagazine.org/supparch/mepower99/cleaner/cleaner.html>
- b) Why: Up to 60% reduction in PM, up to 15% increase in power.

75. NOx adsorber

- a) Source: <http://www.transportation.anl.gov/pdfs/RR/261.pdf>
- b) Why: Up to 90% reduction in NOx. Requires 5 ppm sulfur fuel.

II. Practices for Trucking

II. A. Best Practices – Emission and Cost Reductions

II A.1 Technology - Truck

76. Truck: Auxiliary Power Units (APUs)

- a) Description: APUs, typically based on a small diesel engine, provide heating, air conditioning, and power to maintain a comfortable cabin while the driver rests. This allows the truck engine to be turned off.
- b) Source: <http://www.epa.gov/otaq/smartway/idlingtechnologies.htm#truck-mobile-apugs>
- c) Why: Reduced emissions, fuel consumption, noise, and engine wear.

77. Truck: Direct fired heaters

- a) Description: “A direct fired heater is a small, lightweight, efficient diesel fuel-fired device mounted in the cab of a truck that provides heat for cab comfort. This technology does not include any air conditioning capabilities.” (EPA)
- b) Source: <http://www.epa.gov/smartway/calculator/calculatorexplanation.htm>
- c) Why: Reduced emissions, fuel consumption, noise, and engine wear

78. Truck: Battery powered heating

- a) Description: Uses engine heat to heat the cab, using the battery to circulate coolant with the engine off. Provide heat for up to 4 ½ hours. Shuts off based on low coolant temperature or low battery charge.
- b) Source: <https://www.superiorfg.com/main/SQ/SmartWayTechVendors.aspx>
- c) Why: Reduced emissions, fuel consumption, noise, and engine wear; low cost

79. Truck: Cab Top Deflector, Sloping Hood, Cab Side Flares

- a) Description: Cab Top Deflector - “A straight piece of plastic or fiberglass that extends from the top of the cab at an angle. It usually has open sides and may be retractable.” (EPA)
- b) Source: <http://www.epa.gov/otaq/smartway/documents/aerodynamics.pdf>
- c) Why: Reduced emissions and fuel consumption

80. Truck: Load profile

- a) Description: Keep cargo low and smooth on flatbed trailers.
- b) Source: <http://www.epa.gov/otaq/smartway/documents/aerodynamics.pdf>
- c) Why: Reduces drag, fuel consumption, and emissions... “Secure loose tarpaulins and close the curtains on empty curtain-sided trailers to improve fuel economy by up to 2.5 percent and 4.5 percent, respectively.” (EPA)

81. Truck: Automatic inflation

- a) Description: Equipment which automatically maintains correct tire pressure, adjusting pressure even while vehicle is moving.
- b) Source: <http://www.epa.gov/otaq/smartway/documents/tireinflate.pdf>
- c) Why: Payback period approximately 2 years. May generate additional savings by reducing the risk of tire failure.

82. Truck: Wide base tires

- a) Description: Single, wide tires replace the pair of standard tires. Applies to all axles on a class 8 truck except the front/steering tires.
- b) Source: <http://www.epa.gov/smartway/documents/supersingles.pdf>, <http://airquality2006.tamu.edu/files/presentations/Ang-Olson.pdf>, slide 10
- c) Why: Reduces rolling resistance, weight, and aerodynamic drag. Reduces fuel consumption (4-5%) and emissions, and increases capacity by 800 to 1,000 pounds on weight-limited vehicles. Small reduction in noise. Lower cost yields immediate payback for new trucks. Payback uncertain for retrofits on existing trucks.

83. Synthetic lubricants for engine and transmission

- a) Description: Synthetic lubricants reduce friction compared to conventional oils.
- b) Source: <http://www.epa.gov/smartway/glossary.htm>,
<http://www.royalpurple.com/techrp/summary.html>
- c) Why: Reduced fuel consumption up to 3%, reduced emissions, engine wear, and maintenance.

II A.2 IT - Truck

84. Advanced vehicle routing and scheduling

- a) Description: Integration of route planning with GPS tracking of vehicles. May involve using real-time or historical link travel times for dynamic or probabilistic optimization of routing.
- b) Source:
http://www.lionhrtpub.com/orms/surveys/Vehicle_Routing/vrss14.html
<http://www.mjc2.com/routing.htm>
- c) Why: Increases efficiency, reduces emissions. Potential reduction in fleet size.

85. Truck: Virtual container yard (E-modal), e.g. Ports of LA/LB, Oakland

- a) Description: The virtual container yard is designed to match empty import containers to exports, allowing empty containers to go from an importer directly to an exporter with no intervening call required at marine terminal
- b) Source: <http://www.acta.org/PDF/Virtual%20Container%20Yard.pdf>
- c) Why: Reduces empty trips, thereby reducing emissions and congestion.

86. Freight/load matching

- a) Description: Information on available loads is provided to reduce empty return trips - load boards.
- b) Source: <http://www.epa.gov/smartway/documents/loadmatching.pdf>
<http://www.truck-loads.net/index.asp>
- c) Why: Reduces empty mileage and emissions.

II A.3 Operations - Truck

87. Truck: Driver training/incentive programs

- a) Description: Small changes in driving techniques can reduce fuel consumption by 5% or more. Some studies have shown much larger reductions on fuel consumption.
- b) Source: <http://www.epa.gov/smartway/documents/drivertraining.pdf>
- c) Why: Reduced fuel consumption and emissions.

II A.4 Institutional - Truck

88. Cooperative freight systems

- a) Description: Cooperative freight systems involve multiple companies delivering loads for each other within a given area to increase efficiency.
- b) Source: <http://www.glscs.com/archives/11.98.transportation.htm?adcode=90>
- c) Why: Reduces mileage, costs, and emissions.

II A.5 Infrastructure - Truck

II. B. Air Quality Benefits, Economic Benefits not determined

II. B.1 Technology - Truck

89. Truck: Emulsified Diesel

- a) Description: Water can be emulsified in diesel fuel to reduce emissions. Additives are required to produce a stable mixture. This practice is most feasible for centrally fueled vehicles.
- b) Source: http://www.arb.ca.gov/fuels/diesel/altdiesel/a_spataru.pdf

www.westcoastdiesel.org/fuel-emulsified.htm

<http://www.dieselnet.com/news/2003/09cft.php>

<http://www.lubrizol.com/PuriNOx/>

c) Why: Reduces NO_x (10%-20%), PM (50-60%), and CO₂ (up to 5%).

Potential reduction in peak horsepower.

90. Truck: Fuel borne catalyst

a) Description: A fuel borne catalyst is a metallic catalyst added to fuel which reduces emissions and improves fuel economy.

b) Source: <http://www.fitchfuelcatalyst.com/products/commercial/index.html>

<http://www.dieselnet.com/papers/9909rhodia/>

http://www.greencarcongress.com/2005/09/clean_diesel_te.html

c) Why: Reduces PM, HC, CO, and CO₂ emissions. Fuel economy increases of 3-12% are claimed.

91. Truck: Liquefied Natural Gas, Compressed Natural Gas (LNG/CNG)

a) Description: Existing trucks can be converted to use LNG or CNG.

b) Source: http://www.eere.energy.gov/afdc/progs/new_success_ddown.cgi?44

http://www.westport.com/pdf/WPT-Clean_Air_Corridor_MED.pdf

c) Why: Emission reduction.

92. Truck: Truck stop electrification (on-board or off-board)

a) Description: Truck stops can be equipped to provide heating and cooling for trucks so that idling is not required to maintain a comfortable cabin while the driver sleeps.

b) Source:

<http://www.energy.wsu.edu/documents/renewables/IdlingRestrictions.pdf>

http://www.eere.energy.gov/cleancities/idle/idle_benefits.html

c) Why: Reduced idling, emissions, fuel consumption, engine wear, engine maintenance, and noise.

93. Truck: Automatic shut down and start up

- a) Description: Trucks can be equipped to shut off the engine after a specified time of idling, and to restart the engine when needed.
 - b) Source: <http://www.epa.gov/otaq/smartway/idlingtechnologies.htm#truck-mobile-sdsu>
 - c) Why: Reduced emissions, noise, and fuel consumption. Relatively low cost.
94. Truck: Cab Extenders
- a) Description: Also known as gap seals, reduces the gap between the tractor and trailer to reduce drag.
 - b) Source: <http://www.epa.gov/smartway/documents/aerodynamics.pdf>
 - c) Why: Reduces fuel consumption and emissions.
95. Truck: Low rolling resistance dual tires
- a) Description: Replace conventional dual tires with low rolling resistance dual tires.
 - b) Source: <http://airquality2006.tamu.edu/files/presentations/Ang-Olson.pdf>, slide 10, also NCSU GHG report
 - c) Why: 3% - 5 % fuel savings, emission reduction.
96. Truck: Selective Catalytic Reduction (SCR), e.g. Extengine ADEC
- a) Description: SCR reduces NO_x by injecting ammonia (NH₃) into the exhaust, causing NO_x and NH to form nitrogen and water.
 - b) Source: <http://www.epa.gov/otaq/retrofit/retropotentialtech.htm>
http://www1.eere.energy.gov/vehiclesandfuels/pdfs/deer_2004/session11/2004_deer_aneja.pdf
 - c) Why: NO_x reduced up to 90%, also reduces PM, HC, CO. Increased oil drain interval. Potential reduction in fuel consumption for new engines.
97. Truck: Lightweight materials
- a) Description: Lightweight materials (aluminum, plastic) can be used to reduce the weight of a heavy duty truck by up to 3,000 pounds.
 - b) Source: <http://www.epa.gov/smartway/documents/weightreduction.pdf>
 - c) Why: Fuel consumption reduced by up to 3%. Emission reduction

98. Vehicle computer software upgrade (CARB)

- a) Description: NO_x emissions can be reduced by upgrading vehicle computer software.
- b) Source:
<http://www.arb.ca.gov/msprog/hdsoftware/regdocs/0224presentation.pdf>, including slide 17
- c) Why: Reduced off-cycle NO_x emissions, low cost. (check effect on fuel economy)

99. Electric delivery vehicles

- a) Description: Electric delivery vehicles are being introduced in some countries.
- b) Source:
<http://www.megawattmotorworks.com/display.asp?dismode=article&artid=327>
<http://www.smithelectricvehicles.com/>
- c) Why: Zero emissions (not including electrical generation), up to 50 mph top speed and 120 mile range.

II B.2 IT - Truck

100. Real-time traffic monitoring, probe vehicle system, government could act as clearinghouse for data

II. B3. Operations - Truck

101. Truck: Speed reduction

- a) Description: Some companies have a policy limiting speed; some even control the top speed. Roehl Transport limits speed to 65 mph
- b) Source: <http://www.epa.gov/smartway/documents/reducedspeed.pdf>

<http://www.epa.gov/smartway/partners/roehl-transport.htm>

c) Why: Reduced fuel consumption, emissions, and engine wear. Driving at 65 mph can use up to 20% more fuel than driving at 55 mph.

102. Truck: Double drivers or driver tag teams

a) Description: Some long-distance truck trips are made with two drivers so that one can drive while the other sleeps (double drivers). Tag teams involve one driver going to the first destination, and then a different driver takes over and drives to the next destination.

b) Source: <http://www.epa.gov/smartway/glossary.htm#d>

<http://epa.gov/smartway/documents/2006awards.pdf>

c) Why: Reduces idling, which reduces emissions and engine wear. Faster delivery times. (Check overall cost comparison – might be a savings since it could reduce the size of the fleet and maintenance costs. Could it substitute for air freight at some distances?)

II. B.4 Institutional - Truck

103. Night deliveries or off-peak deliveries

a) Why: Night deliveries and off-peak deliveries reduce congestion and emissions from idling. Night deliveries also shift emissions to times of day/night when emissions and air quality problems are less serious. Seven Eleven in Japan makes all deliveries at off-peak hours.

104. Emission inspection programs

a) Description: As of 2004, there are 16 truck emission inspection programs in the US. Program types include roadside inspection, periodic inspection at an inspection facility, and self-certification for fleets.

b) http://www.arb.ca.gov/msprog/hdvp/inspection_study.pdf

c) Why: 5-7% of pre-1998 trucks exceed smoke emission standards. The percentage failing increases with increasing vehicle age.

105. Low Emission Zones (LEZ)
- a) Description: An LEZ is an area which requires meeting a specified level of emissions standards in order to enter. LEZs have been in effect in Sweden since 1996, and an LEZ is planned for London, which is proposed to cover the entire Greater London area. LA/LB ports plan to require 2007 or later trucks beginning in 2013 (check date), which could be considered a low emission zone.
 - b) Source:
http://www.airquality.co.uk/archive/reports/cat09/0505171128_London_Low_Emission_Zone_Detailed_Assessment.doc
<http://www.tfl.gov.uk/tfl/low-emission-zone/pdffdocs/LEZ-RTM-chapters.pdf>
 - c) Why: Accelerates the deployment of newer, lower emission vehicles. A study of the Stockholm LEZ estimated that PM emissions from heavy duty vehicles were reduced by 40% compared to the reductions which would have occurred otherwise. Due to the differing needs among areas (e.g. areas with high ambient levels of pollutants have greater needs for emission reductions); LEZs can achieve reductions in those areas without placing undue burdens on other areas.
106. Road pricing
- a) Description: Charging different fees for using roads based on time of day and class of vehicle.
 - b) Source: <http://onlinepubs.trb.org/onlinepubs/millennium/00044.pdf>
 - c) Why: Road pricing can increase the efficiency/utilization of the infrastructure. By shifting traffic to less busy periods, congestion and emissions can be reduced.
107. Congestion charge to enter city, e.g. London
108. Age-based vehicle fee

- a) Description: External costs (e.g. emissions) of freight transportation vary with the age of the vehicle. Charging a higher fee for higher-polluting vehicles is one way to implement the “polluter pays” principle. Example: Swiss heavy vehicle fee.
 - b) Source:
 - http://www.eastwesttc.org/websites/eastwest/sd_page/54/BalmerMalm%C3%B6%2011.9.pdf
 - <http://www.are.admin.ch/are/en/verkehr/lsva/index.html>
 - c) Why: The heavy vehicle fee in Switzerland (as a whole, not just the age-based component) lowered vehicle-kilometers while freight volume increased. Age-based fees encourage the use of newer, lower-emission trucks, and collect fees which can be used to mitigate the negative effects of freight transportation.
109. Load factor requirements (Amsterdam, Copenhagen)
- a) Description: Municipalities may require that any truck entering the city, or a portion of the city, meet a minimum load factor. Examples are Amsterdam and Copenhagen.
 - b) Why: Load factor requirements force a higher utilization of truck capacity, thereby reducing VMT, congestion, and emissions.
110. Truck type/time restrictions
- a) Description: Restrictions on large trucks in urban areas during peak periods have been proposed in some cities. The intent is to shift traffic to off-peak periods, thereby reducing congestion and emissions.
 - b) Source: http://www.start-project.org/download/Riga%20Peer-to-Peer%20Workshop%20-%20Recommendation%20report%20_Final.pdf
http://www.findarticles.com/p/articles/mi_qa3705/is_199501/ai_n8733263
 (find link to full paper)
 - c) Why: Effects of such a restriction are not clear, and it could result in a switch to smaller vehicles to avoid the time restrictions.
111. Fuel efficiency standards for heavy duty trucks

- a) Description: Despite the cost-effectiveness of technologies to improve fuel economy of heavy duty trucks, adoption of many of these technologies is limited. Fuel efficiency standards would necessitate the adoption of such technologies. A standard of 9.8 miles per gallon by 2015 may be feasible. Japan has established fuel economy standards for heavy duty trucks and buses.
 - b) Source: <http://www.energycommission.org/files/finalReport/III.4.a%20-%20Heavy-Duty%20Trucks.pdf>
http://www.japantransport.com/newconference/2006/03/dme_detailed_information.pdf (see page 5)
http://www.avl.com/wo/webobsession.servlet.go/encoded/YXBwPWJjbXMmcGFnZT12aWV3Jm5vZGVpZD00MDAwMjExMDI_3D.html
 - c) Promotes/requires adoption of technologies which reduce fuel consumption. Criteria pollutants and GHG emissions would also be reduced.
112. Public assistance for purchase of new truck or retrofits
- a) Trucks for some operations, such as drayage, are often owned by independents, which may have difficulty affording newer, cleaner vehicles or paying for retrofits.
113. Booking system for (urban) truck parking spaces
114. Change route: control access of large trucks to city or recommend/designate truck routes
115. Standards for ITS interoperability
116. Access restrictions to promote off-peak deliveries, cleaner vehicles, and higher load factors
- a) Source:
<http://www.its.ucdavis.edu/events/outreachevents/asilomar2005/presentations/Jackson.pdf>, slide 7
117. Parking priority for Low Emission Vehicles
118. Signal priority for trucks (slower acceleration causes delays for all vehicles)
119. Truck idling restrictions

- a) Description: Many states have passed anti-idling regulations, some targeting urban areas, some statewide.
 - b) Source: <http://www.cleanairfleets.org/idling.html>
 - c) Why: Each year a typical class 8 truck emits 0.3 tons of NOx and 21 tons of CO₂ from idling. Idling also causes engine wear, and reduces oil life by 75%.
120. FAST lanes at border crossings for CTPAT cargo
- a) Source:
http://cantruck.com/news/releases/2007/prel_2007_02_02_171015_rt.php3
121. Require staging areas for trucks at buildings
122. Incident management program or truck safety hotline
123. Incentives to avoid “binge” buying of pre-2010 trucks
- a) Source:
http://cantruck.com/news/releases/2007/prel_2007_01_31_114827_rt.php3
 - b) Why: Excess purchase of pre-2010 trucks would delay the emission benefits of the regulations, and could also decrease stability of employment in the truck manufacturing industry.
124. Require all trucks to limit top speed electronically.
- a) Description: All class 7 and 8 trucks built since 1991 have the capability to govern top speed. The American Trucking Association supports using a tamper-proof device on new trucks to limit speed to 68 mph.
 - b) Source: <http://www.etrucker.com/apps/news/article.asp?id=56259>
<http://cantruck.com/speedlimiters/>
 - c) Why: Reduced fuel consumption, emissions, equipment wear, and liability costs. Increased safety. Addresses the incentive to speed as a competitive advantage.

II. B.5 Infrastructure - Truck

125. Integrated Logistics Centers
- a) Source: http://www.csx.com/?fuseaction=media.news_detail&i=48058
 - b) Why: Efficiency, reduced costs (check environmental benefits)
126. Highway maintenance
- a) Description: Pavement in good condition has less rolling resistance. (Studies of differences between fuel consumption for asphalt and concrete have not been conclusive.)
 - b) Source: <http://www.eurobitume.org/Html/Fuel/Fuel%20Efficiency-Executive%20Summary.pdf>
 - c) Why: Reduced fuel consumption and emissions. One study showed that pavement rehabilitation reduced fuel consumption of trucks by 4.5%.
127. Weigh in motion scales
- a) Description:
 - b) Source: http://www.wsdot.wa.gov/News/2005/02/Feb01_I5BowHill.htm
<http://www.geog.buffalo.edu/~jcthill/WBSection11.pdf>
<http://www.itsbenefits.its.dot.gov/its/benecost.nsf/ID/4F5EB146673D6447852570AB00644124?OpenDocument>
 - c) Why: Reduces delays/idling/emissions. Potential to reduce highway construction costs.
128. Public freight terminals
- a) Description: Public freight terminals are often located ...
 - b) Why: Public freight terminals facilitate cooperative freight systems
129. Protect suburban freight centers (from encroachment of other development)
130. Zone for freight facilities near freeway interchanges. Reduces freight traffic through residential areas.

- 131. Location of facilities, including logistics terminals – simplify hierarchy of physical distribution
- 132. Retain existing industrial areas
- 133. Electronic toll collection
- 134. Lane adds
- 135. Dedicated lanes or entire roads to trucks
- 136. Intersection improvements
- 137. Signage for improved way-finding
- 138. Signal timing/coordination
 - a) Source:
http://www.fhwa.dot.gov/environment/conformity/mpe_benefits/4.htm
 - b) Why: Because of their slow acceleration, trucks introduce additional delays to overall traffic flow.

II. C. Air Quality Benefits, Increased Costs - Truck

- 139. Truck: DPF retrofits
 - a) Description: Diesel particulate filters can be retrofitted on 1994 – 2006 trucks. Limited availability for 1991 – 1993 models.
 - b) Source: <http://airquality2006.tamu.edu/files/presentations/Ang-Olson.pdf>, slide 11
 - c) Why: PM reduced 80-90%. Potential small penalty in fuel economy.
- 140. Truck: Diesel Oxidation Catalyst (DOC) - base metal type
 - a) Description: DOCs cause reactions which turn emissions into harmless gases
 - b) Source: <http://www.cleanairfleets.org/ect.html>
<http://www.epa.gov/otaq/retrofit/retropotentialtech.htm>
 - c) Why: Reduces PM 10-40%, HC 50%, CO 50%, cost \$1-2K, requires no maintenance. 0% to 2% fuel consumption penalty.

141. Truck: Catalyzed converter/muffler
- a) Description:
 - b) Source: <http://www.epa.gov/otaq/retrofit/retroverifiedlist.htm>
<http://www.cat.com/cda/files/333627/7/pehj0055.pdf>
 - c) Why: 20% reduction in PM, 20-90% CO, 40-90% HC; no maintenance required, does not require ULSD, no effect on fuel economy or engine life
142. Truck: Flow-through filter
- a) Description: Flow-through filters typically use a catalyzed wire mesh to reduce PM.
 - b) Source: <http://www.dieselforum.org/technology-spotlight/technology-definitions/>
 - c) Why: Reduced PM 30-70%, especially suited to older, higher-emissions engines.

II. D. Pilot and Concept Practices - Truck

143. NO_x storage and reduction catalysts (check applicable modes)
- a) Source: <http://staff.chemeng.lth.se/~IngemarO/noxstorage.shtml>
http://www.ict.uni-karlsruhe.de/index.pl/themen/nox_speicherkat/index.html
144. SCR using hydrocarbons (i.e. diesel fuel) as reductant
- a) Source: http://www.rsc.org/images/CA018004_tcm18-15823.pdf
145. Hybrid delivery trucks, e.g. UPS, FedEx
- a) Why: Substantial reductions in emissions and fuel consumption; also quieter
 - b) Source:
<http://www.its.ucdavis.edu/events/outreachevents/asilomar2005/presentations/Jackson.pdf>, slides 11 – 16
<http://www.todaystrucking.com/newscenter.cfm?pageaction=story&intNewsCenterID=11&intDocID=17281&CFID=1555769&CFTOKEN=30890932>

- c) Why: 42% increase in fuel economy, reduced CO₂, NO_x, PM, and CO.
146. Fuel cell delivery trucks – UPS and FedEx pilots
- a) Source:
<http://www.its.ucdavis.edu/events/outreachevents/asilomar2005/presentations/Jackson.pdf>, slide 8
147. Pneumatic blowing
148. Powertrap (electrostatic precipitation), may be more effective than DPF
149. Waster heat recovery
150. Electric accessories (check whether commercially available)
- a) Description: A/C compressor, air pump, oil pump, and water pump can be electrically powered.
 - b) Source: http://www.ctre.iastate.edu/pubs/truck_idling/virden.pdf
 - c) Why: Reduces fuel consumption and emissions. Some electric accessories are also more reliable than their mechanically-driven counterparts.
151. Fuel cell powered accessories
152. Diesel Oxidation Catalyst (Precious Metal)
- a) Description: DOCs cause reactions which turn emissions into harmless gases
 - b) Source: <http://www.cleanairfleets.org/ect.html>
<http://www.epa.gov/otaq/retrofit/retropotentialtech.htm>
 - c) Why: Reduces PM 20-40%, HC 90%, CO 90%, cost \$1-3K, requires no maintenance. 0% to 2% fuel consumption penalty.
153. Dimethyl ether (DME)
- a) Description: DME can be produced from coal, and produces lower emissions
 - b) Source:
http://www.japantransport.com/newconference/2006/03/dme_detailed_information.pdf
http://www.greencarcongress.com/2005/12/toyo_engineerin.html
 - c) Why: Can be used in compression (diesel) engines. Test showed NO_x emissions 60% below EPA 2010 standards, and PM emissions 85% below

EPA 2010 standards. Zero SOx emissions. CO emissions also very low. Fuel efficiency the same as diesel fuel.

154. Electric dray trucks (pilot at LA)
- a) Source:
http://www.portoflosangeles.org/Press/REL_EPA_Hybrid_Yard_Hostler_Project.pdf
155. Fuel cell pallet truck
- a) Source: http://www.greencarcongress.com/2007/01/cellex_complete.html

II. E. Not Categorized Practices - Truck

156. Increased peak cylinder pressures
- a) Description: Increase cylinder pressure to improve efficiency.
 - b) Source: NCSU GHG report
 - c) Why: Reduced fuel consumption and emissions.
157. Improved fuel injectors
- a) Source: NCSU GHG report
 - b) Why: Estimated fuel economy increase of 6%, reduced emissions
158. Turbocharged direct injection
159. NOx adsorber
- a) Description: “Unlike catalysts, which continuously convert NOx to N₂, NOx adsorbers are materials which store NOx under lean conditions and release and catalytically reduce the stored NOx under rich conditions.” Commercially available on light duty vehicles in Europe.
 - b) Source: <http://www.epa.gov/otaq/retrofit/retropotentialtech.htm>
<http://www.dieselnet.com/papers/9712bailey/>
 - c) > 90% NOx reduction
160. Mobile data terminals (may include GPS)

III. Practices for Ocean

III. A. Best Practices - Emission and Cost Reductions

III A.1 Technology - Ocean

161. Propeller polishing and repair of edge damage, up to 5% improvement in fuel consumption.

III A.2 IT - Ocean

III A.3 Operations - Ocean

162. Vessel speed reduction
- a) Description: Vessel speed reduction near a port or coast causes a decrease in emissions and fuel consumption. Voluntary program in LA.
 - b) Source: <http://www.arb.ca.gov/ports/marinevess/vsr/docs/pres07122007.pdf>
 - c) Why: Large decrease in emissions and in fuel consumption. (probably larger decrease in emissions than using 1.5% sulfur fuel in SECA,– check, also no issues with switching fuels)

III A.4 Institutional - Ocean

III A.5 Infrastructure - Ocean

III. B. Air Quality Benefits, Economic Benefits not determined

III. B.1 Technology - Ocean

163. Fuel catalyst
- a) Source: CombustAll
 - b) Why: Emission reduction, claims fuel consumption reduced 3.5%
164. Emulsified diesel
- a) Description: Description: Water can be emulsified in diesel fuel to reduce emissions. Additives are required to produce a stable mixture. This practice is most feasible for centrally fueled vehicles.
 - b) Source:
http://www.marad.dot.gov/nmrec/energy_technologies/images/MAN%20B&W.pdf
<http://www.northeastdiesel.org/pdf/2006-0425--BostonHarborScopingFinalReport.pdf>
 - c) Why: 0- 50% reduction in NOx. APL begins testing in February 2007, and expects NOx reduction up to 20% (December 18, 2006 Shipping Digest)
However, “It should be noted that the use of emulsified fuel in marine vessels has both cold weather issues in New England as well as potential hull/fuel tank corrosion issues that have not been fully vetted by USCG.”
165. Advanced cylinder lubricating system
- a) Source: December 18, 2006 Shipping Digest
 - b) Why: Reduces lube oil consumption by 20% - 50%, reduces PM
 - c) APL planning test
166. Alternative Marine Power (AMP)
- a) Description: Also know as “shore power” or “cold-ironing”

- b) Source: (cost-effectiveness)
http://www.northeastdiesel.org/pdf/Marine_Locomotive_Retrofit_Progress_11oct06.pdf
- c) Why: Near complete reduction of hoteling emissions
- 167. Off-center propeller
- 168. Propeller boss cap with fins
 - a) Description: Increases efficiency by 4%-5%
 - b) Source: http://www.ship-technology.com/projects/courageous_ace/
- 169. Auxiliary free-rotating propulsion device behind main propeller
- 170. Low NOx conversion (change compression and injection timing/rate);
 Wartsila claims improved fuel economy, TL Garret says fuel economy is worse
- 171. Aerodynamic hull design for car carriers
 - a) Description: New designs reduce wind resistance, fuel consumption, and emissions. 5% improvement in fuel efficiency.
 - b) Source: <http://www.mol.co.jp/pr-e/2004/e-pr-2423.html>

III B.2 IT - Ocean

III. B3. Operations - Ocean

- 172. Short Sea Shipping
 - a) Description: Short sea shipping substitutes an additional ocean leg for part of the land portion.
 - b) Why: Depending upon distances, cost and emission reductions can exceed the cost and emissions of the additional handling. Potential reduction in highway congestion.

III. B.4 Institutional - Ocean

III. C. Air Quality Benefits, Increased Costs - Ocean

- 173. Marine: MDO/MGO in auxiliary engines within 24 miles of coast
 - a) Source/example: CARB requirement
 - b) Why: large reduction in SO_x and PM
- 174. Marine: MDO in main engines
 - a) Source/example: pending CARB requirement
 - b) Why: large reduction in SO_x and PM, CARB claims it's cost effective in \$/ton
- 175. SECA for N. America
- 176. Worldwide SECA
- 177. Eliminate all use of residual oil (Intertanko proposal)
- 178. MDO within 24 miles of coast for main engines, e.g. CARB upcoming requirement
- 179. MDO within 200 miles of coast (has been discussed in Europe)

III. D. Pilot and Concept Practices - Ocean

- 180. Scrubber for hoteling vessels (alternative to AMP - no change required to vessels)
- 181. Fuel cell propulsion
- 182. Pod propulsion (currently limited to ~ 20MW, high temperature superconducting will increase)
- 183. Polymer drag reduction
- 184. Pentamaran (concept)
- 185. Ionization emissions scrubber (Maersk trial)

III. E. Not Categorized - Ocean

- 186. High performance nozzles, up to 15% improvement
- 187. Seawater scrubbing – may be more cost effective than 1.5% fuel in SECA
- 188. Turbocharger and after-cooler in engine coolant loop
- 189. Slide valve retrofit, standard on new 2-stroke diesels
- 190. Humid air motor (Combustion Air Saturation System)
 - a) Why: Reduced emissions, no change to fuel consumption.
- 191. Marine: Alliances (increased load factors and thus reduced emissions? check)
- 192. Spray oil injection
 - a) Description: Spray oil injection reduces lube oil consumption and PM emissions.
 - b) Source: <http://www.marinetalk.com/articles-marine-companies/art/New-Car-Carrier-Features-Advanced-Technologies-MIT025122222TU.html>

IV. Practices for Inland Waterborne

IV. A. Best Practices - Emission and Cost Reductions

IV. A.1 Technology - Inland Waterborne

IV. A.2 IT - Inland Waterborne

IV. A.3 Operations - Inland Waterborne

IV. A.4 Institutional - Inland Waterborne

IV. A.5 Infrastructure - Inland Waterborne

IV. B. Air Quality Benefits, Economic Benefits not determined

IV. B.1 Technology - Inland Waterborne

IV B.2 IT - Inland Waterborne

IV. B3. Operations - Inland Waterborne

193. Container on barge is competitive with trucking in some areas. Reduces CO₂, reduction of other pollutants depends upon age of vehicles.
194. Covered inland barge terminals (able to operate in all weather conditions)
195. Tri-modal terminals (inland water, rail, truck)

IV. B.4 Institutional - Inland Waterborne

IV. B.5 Infrastructure - Inland Waterborne

196. Improve inland waterways to prevent further loss of modal share. Water transport has lower emissions than trucking.

IV. C. Air Quality Benefits, Increased Costs - Inland Waterborne

197. B20 biodiesel for Category 1 & 2 vessels
- a) Description: Biodiesel can be used in most marine engines (check)
 - b) Source: <http://www.eia.doe.gov/oiaf/analysispaper/biodiesel/>
 - c) Why: Biodiesel has lower sulfur, so SO_x and PM emissions are reduced. Biodiesel is carbon-efficient, reducing net carbon emissions. (compare B20 price with tax credit to current diesel price)

IV. D. Pilot and Concept Practices - Inland Waterborne

198. New generation inland container ships

V. Practices for Port/Terminal

V. A. Best Practices - Emission and Cost Reductions

V. A.1 Technology - Port/Terminal

V. A.2 IT - Port/Terminal

V. A.3 Operations - Port/Terminal

199. Use smaller or low emission vehicles to transport personnel at port, e.g. Norfolk, Everett ports

V. A.4 Institutional - Port/Terminal

V. A.5 Infrastructure - Port/Terminal

200. On-dock and near-dock rail
- a) On-dock or near dock rail, coupled with an inland container terminal, can reduce truck traffic, especially in urban port areas.
 - b) Source: (see Halifax plans, Shipping Digest, 2/12/07, with comments by Mary Brooks), NY PIDN, Express Rail
 - c) Why: Reduced highway congestion and emissions. Potential increase in capacity.

V. B. Air Quality Benefits, Economic Benefits not determined

V. B.1 Technology - Port/Terminal

201. Trailer Positioning System
 - a) Description: Uses sensors and lights to help trucks stop in the correct position under a crane.
 - b) Source: <http://www.portautomation.com/shipLoad/shipLoad.htm>
 - c) Why: Increases speed, reduces accidents/damage, reduces driver fatigue.
202. Gate appointment system
 - a) Description: An appointment system, generally through the internet, is used to schedule trucks arrivals at the terminal.
 - b) Source: <http://www.epa.gov/smartway/documents/420f06005.pdf>
 - c) Why: Reduces delays and idling/emissions, better utilizes terminal capacity.
203. Automated gate operations, using OCR
 - a) Description: Optical character recognition can be used to identify trucks entering (or leaving?) a terminal, and can also be used to identify containers as they are unloaded from a vessel.
 - b) Why: Increases speed of gate operations, reduces idling/emissions.
204. Fuel borne catalyst
 - a) Source: <http://www.fitchfuelcatalyst.com/products/commercial/index.html>
 - b) Why: reduces emissions, claims fuel economy increase of 5-12%
205. CNG/LNG
 - a) Source: http://www.eere.energy.gov/afdc/altfuel/gas_benefits.html
 - b) Why: 90+% PM reduction, 50+% NOx reduction
206. B20 biodiesel for Category 1 & 2 vessels
 - a) Source: <http://www.eia.doe.gov/oiaf/analysispaper/biodiesel/>

- b) Why: Biodiesel has lower sulfur, so SO_x and PM emissions are reduced.
Biodiesel is carbon-efficient, reducing net carbon emissions.
- 207. Electric regenerating cranes, for on-terminal rail yard
- 208. Electric RTG (Oslo), RMG (ECT, Rotterdam)
- 209. Multi-lift crane configurations, e.g. tandem/quad cranes (Dubai – check. See AAPA Facilities Engineering Conference, JWD presentation)
 - a) Why: Reduces the amount of time spent in port, reducing hoteling emissions.
- 210. Oxygenated diesel for CHE
- 211. Terminal automation. Automation increases capital costs but decreases operating costs.
 - a) Automatic guided vehicles
 - b) Automated yard crane – RMG.
 - c) Fully automated sorting of containers
- 212. End loaded container yard – trucks shut off engine while waiting
- 213. Radiation portal monitor
- 214. Automated mooring
 - a) Description: Automated mooring systems reduce the time required to secure the vessel.
 - b) Source:
http://www.ffca2006.com/documents/presentations/gen_tuesday/Peter%20Vanderdermat.pdf
 - c) Why: Reduced time at berth, reducing emissions.
- 215. Automated X-ray inspection, e.g. Hong Kong

V B.2 IT - Port/Terminal

- 216. Electronic container seals (need standardization)
- 217. Terminal simulation to evaluate strategies

V. B3. Operations - Port/Terminal

- 218. Chassis pools
- 219. Yard chassis
- 220. Multi-trailer (truck) train for transporting containers at the terminal
- 221. New generation terminal designs, e.g. ECT, Rotterdam
- 222. Pre-staging of boxes on chassis with RMG/RTG
- 223. Extended gate hours
- 224. Port truck congestion pricing, e.g. Pierpass (night gate operations with price differential)
- 225. Some ports assign different arrival times to different containers on a vessel (not all unloaded at the same time); helps spread demand, which eases congestion and reduces idling/emissions.

V. B.4 Institutional - Port/Terminal

- 226. Use lease requirements to reduce emissions
- 227. Impact fees
- 228. Emission performance standards
 - a) Description: Emission standards can be required by tenant leases at ports, as done at San Pedro. Emission standards can also be accomplished using incentives and tariffs. The performance standards can be based on fleet averages for trucks, cargo handling equipment, and harbor craft.
 - b) Source: http://www.portoflosangeles.org/DOC/CAAP_Fact_Sheet_Final.pdf
 - c) Why: These approaches are believed capable of producing large reductions in emissions (~50%) within five years.

V. B.5 Infrastructure - Port/Terminal

229. Improved terminal layouts can increase efficiency and reduce emissions.

V. C. Air Quality Benefits, Increased Costs - Port/Terminal

230. ULSD in CHE prior to requirement in 2010
- a) Why: Reduction in SO_x and PM. Relatively small increase in fuel cost.
231. DOC for CHE with 500 ppm fuel
- a) Source:
http://www.northeastdiesel.org/pdf/Marine_Locomotive_Retrofit_Progress_11oct06.pdf, slide 10
<http://www.northeastdiesel.org/pdf/2006-0425--BostonHarborScopingFinalReport.pdf>
- b) Why: Up to 20% - 40% reduction in PM
232. Catalyzed wire mesh filter
- a) Description:
- b) Source: <http://www.northeastdiesel.org/pdf/2006-0425--BostonHarborScopingFinalReport.pdf>
- c) Why: A catalyzed wire mesh filter removes more particulate matter than a DOC, and does not require as high exhaust temperature as a DPF. PM reductions are 55-76% when used with a fuel-borne catalyst.
233. Indented berth with loading/unloading from both sides of vessel
- a) Source:
http://www.ffca2006.com/documents/presentations/gen_tuesday/Peter%20Vandermaat.pdf

V. D. Pilot and Concept Practices - Port/Terminal

234. Emission trading programs, e.g. Chicago Climate Exchange, EPA NO_x trading program for power plants
235. Hybrid yard tractors
- a) Description: Hybrid yard tractors are expected to provide large reductions in emissions and fuel consumption. Reduced operation and maintenance costs, but higher initial cost.
 - b) Why: Projected reduction 93% for NO_x and PM. Reduction in fuel consumption and GHG, less noise than conventional units
236. Stationary emission control equipment
- a) Description: Stationary equipment can be used to reduce emissions for hoteling vessels, similar to locomotive ALECS project. The same equipment will be used at a port after the completion of the locomotive ALECS project.
 - b) Source: <http://www.arb.ca.gov/railyard/ryagreement/071306placer.pdf>
 - c) Why: SO_x, NO_x, and PM reduced by 95%-99%.
237. Electric dray trucks
- a) Source:
http://www.portoflosangeles.org/Board/2007/January/010407_item16.pdf
238. Rapid container handling technologies, e.g. double and quad container handling can reduce vessel berthing emissions.

VI. ALL MODES

VI. A. ALL MODES – IT

239. Environmental Management Systems (ports, carriers, shippers), e.g. Freight Logistics Environmental and Energy Tracking (FLEET)
Some of the benefits of developing an EMS include:
-Improved community relations and public image-Cost savings-Improved internal communication-Increased competitiveness and market opportunities
(<http://www.northeastdiesel.org/pdf/locomotive-report-june-2006.pdf>)

VI. B. ALL MODES – Institutional

240. Non-monetary incentives, such as public recognition for emission reductions.
241. Change mode: from truck to inland waterway, rail, or underground
242. Company-wide emission reduction targets, e.g. Otto Versand for CO2
- a) Description: Some companies have targets for emission reductions from freight transportation.
- b) Source:
http://www.pewclimate.org/companies_leading_the_way_belc/targets/
- c) Why: Encourages efficiency, reduced emissions, and reduced costs.
243. Encourage purchase of local goods
244. All: Tax incentives for emission reduction technology
- a) Description: Tax incentives, e.g. credits, to cover part of the cost of retrofits.

- b) Source:
 - <http://209.85.165.104/search?q=cache:ixPgzFH71bkJ:www.deq.state.or.us/aq/factsheets/03-AQ-007CleanDiesel.pdf+freight+emission+tax+incentive&hl=en&gl=us&ct=clnk&cd=1>
 - c) Why: Retrofits can result in large reductions in diesel emissions, and carriers typically lack the economic incentive to invest in emission reduction technology.
245. All: Coordinate freight planning among cities within a region. Create regional and state boards to coordinate freight policy and planning
- a) Description: Freight planning is often performed by cities independently. Opportunities for coordination within a region.
246. Avoid new development of sensitive land uses near major roads and freight facilities, e.g. CARB Land Use Handbook
247. Encourage movement of freight through attainment areas w/ low congestion
248. Encourage re-use of brownfields
249. Better cargo forecasting as well as improved communication and cooperation among transportation modes will improve system efficiencies over the long term.

VI. C. ALL/NEW MODES – Pilot/Concept

250. Coal gasification and Fischer-Tropsch fuels
- a) Source: <http://featured.matter-mag.com/2006/11/can-coal-clean-transportation-fuel.cfm> (look for another source)
251. Coal log pipeline – research claims it's more efficient than train or coal slurry pipeline
252. Homogeneous Charge Compression Ignition (HCCI)
- a) Source: http://www.greencarcongress.com/2006/10/caterpillars_va.html

253. Variable Compression Ratio Engines
- a) Source: http://www.greencarcongress.com/2006/10/caterpillars_va.html
254. Non-Thermal Plasma Catalysts
255. Environmental tax (emissions tax)
- a) Description: Since a direct ("ideal") emissions tax is not practical, this approach takes the form of alternatives such as fuel tax or vehicle mile tax.
- b) Source: <http://www.bepress.com/fullertonwest/frontmatter.pdf>
- c) Why: An emissions tax may be one of the most economical ways to reduce emissions. "... economic theory suggests that costs of achieving any particular level of air quality can be minimized by the use of incentive policies such as permits, taxes, or subsidies. If an individual has to pay the price of a permit or pay a tax per unit of emissions, then that individual has the incentive to find all of the cheapest and most convenient ways to reduce emissions."
256. Improved lubrication, friction modifiers
- a) Why: Fuel consumption reduced. Reduced emissions.

VII. Unlikely Candidates for “Best” Practice

257. Truck: B20 biodiesel
- a) Source: <http://www.epa.gov/otaq/models/analysis/biodsl/p02001.pdf>
 - b) Why: small reduction in PM, higher cost, slightly higher NO_x. (check concerns on engine wear)
258. Truck: Ethanol
- a) Lower energy density
<http://www.greenhouse.gov.au/transport/comparison/pubs/2ch6.pdf>
 - b) Lower NO_x and PM, but higher CO and HC
<http://www.eere.energy.gov/afdc/pdfs/truck6-3.pdf>
259. Marine: Direct water injection for fuel w/ < 1.5% sulfur
- a) Requires supply of fresh water (uses more water than fuel)
260. Truck: Lean NO_x catalyst + DPF
- a) Lean NO_x catalyst uses fuel instead of ammonia as the reducing agent.
 - b) Source: <http://www.arb.ca.gov/diesel/verdev/vt/cvt.htm>
<http://www.epa.gov/otaq/retrofit/retropotentialtech.htm>
 - c) Why: 20-25% reduction on NO_x, 85% PM reduction. 4-7% fuel penalty.
261. Truck: EGR retrofit
- a) Description: EGR can be retrofitted
 - b) Source: <http://www.cleanairnet.org/infopool/1411/propertyvalue-17742.html>
 - c) Why: Low pressure EGR can be retrofit without engine modifications.
Reduces NO_x up to 50%. However, fuel economy is reduced.