Spring 2006

Reducing the Localized Cancer Risk: Determining the Feasibility for Reducing Diesel Particulate-Matter Emissions from Heavy-duty Diesel Trucks in Containerized Movement Operations Near the Port of Long Beach

John Kato

GOLDEN GATE UNIVERSITY

REDUCING THE LOCALIZED CANCER RISK: DETERMINING THE FEASABILITY FOR REDUCING DIESEL PARTICULATE-MATTER EMISSIONS FROM HEAVY-DUTY DIESEL TRUCKS IN CONTAINERIZED MOVEMENT OPERATIONS NEAR THE PORT OF LONG BEACH

By John Kato

EMPA 396

Spring I, 2006

Instructor: Dr. Joaquin Gonzalez

CONTENTS

ABSTRACT

In August 1998, the California Air Resources Board identified diesel particulate-matter as a toxic air contaminant. In addition to the identification, the Office of Environmental Health Hazard Assessment found that exposures to diesel particulate-matter (diesel PM) resulted in increased risk of cancer and an increase in chronic noncancer health effects including a greater incidence of cough, labored breathing, chest tightness, wheezing, and bronchitis (DRRP, 2000). Though federal, state, and local regulatory endeavors are active towards minimizing diesel PM exposure, such endeavors typically involve a resolution requiring an implementation time frame of five to ten years that may not necessarily address localized exposure.

This paper investigates the current health impacts of diesel particulate-matter exposure from heavy-duty diesel trucks transporting containers from the Port of Long Beach on a specific neighborhood along the 710 corridor. The current health assessment will be correlated with the number of trucks traveling within a one-mile radius of the neighborhood as well as the diesel PM emitted. This paper also investigates the feasibility of modernizing the heavy-duty diesel trucks that conduct container movement operations to 2003-model-year-engines by 2010. The subsequent health benefits from fleet modernization by residents near the Port of Long Beach will be realized.

REDUCING THE LOCALIZED CANCER RISK: DETERMINING THE FEASABILITY FOR REDUCING DIESEL PARTICULATE-MATTER EMISSIONS FROM HEAVY-DUTY DIESEL TRUCKS IN CONTAINERIZED MOVEMENT OPERATIONS NEAR THE PORT OF LONG BEACH

INTRODUCTION

Particulate-matter emissions from diesel-fueled vehicles and engines are about 28,000 tons per year in California. These emissions come from a wide variety of sources including over one million on-road and off-road vehicles, about 16,000 stationary engines, and close to 50,000 portable engines. On-road engines account for about 27 percent of the emissions. With full implementation of current vehicle standards and vehicle turnover, diesel particulate-matter (diesel PM) will still be about 22,000 tons per year in 2010 and about 19,000 tons per year in 2020 (DRRP, 2000).

In 1988, following an exhaustive 10-year scientific assessment process, the California Air Resources Board (ARB) identified particulate-matter from diesel-fueled engines as a toxic air contaminant (TAC). On a statewide basis, the average potential cancer risk associated with these emissions is over 500 potential cases per million. In the southern California air basin, the potential risk associated with diesel PM emissions is estimated to be 1,000 per million people. Compared to other air toxics that the ARB has identified and controlled, diesel PM emissions are estimated to be responsible for about 70 percent of the total ambient air toxics risk. In addition to these general risks, diesel PM can also present elevated localized or near-source exposures. Depending on the activity and nearness to receptors, these potential risks can range from 10 to 1,500 per million or more (DRRP, 2000).

In regards to goods movement, Southern California is host to the nation's third busiest waterborne freight gateway for international merchandise trade by value of shipments. In 2004, over 6.2 million containers passed through the Port of Long Beach. The projected increase of containerized goods is expected to reach 10 million by 2010 (POLB, 1999). Rail transports approximately 25 percent of these goods, while heavy-duty diesel trucks transport 75 percent. As Freeway 710 is one of the major transportation arteries leading to and from the Port of Long Beach, approximately 25,000 heavy-duty diesel trucks travel this route daily (CalTrans, 2004). These trucks contribute approximately 150 tons of diesel PM a year (ARB, 2005).

Though the emissions from these trucks only contribute approximately one percent of the total statewide diesel PM emissions, the concentrated localized exposure to the surrounding neighborhoods is significant. As the families in the surrounding neighborhoods are predominately low income with minimal education (EJ, 2003), the ability for these residents to relocate is extremely limited.

This research paper investigates the current health impacts of diesel particulate-matter exposure from heavy-duty diesel trucks transporting containers from the Port of Long Beach on a specific neighborhood along the 710 corridor. The current health assessment will be correlated with the number of trucks traveling within a one-mile radius of the neighborhood. This paper also investigates the feasibility of modernizing the heavy-duty diesel trucks that conduct container movement operations to 2003 model year engines by 2010. The subsequent health benefits from fleet modernization by residents near the Port of Long Beach will be realized.

LITERATURE

A search of relevant literature found a significant number of studies/articles directly addressing areas of diesel PM emissions, corresponding control strategies, diesel PM health impacts, heavy-duty diesel truck operations, environmental justice communities, regulatory activities, and California's import/export activities. Several groups of studies in particular lay the foundation for addressing this research project.

As the research project involves the impacts of air pollution, specifically diesel particulate-matter on a Environmental Justice community near one of the major traffic points from the Port of Long Beach/Los Angeles, an ongoing study titled *Association between Air Pollution and Lung Function Growth in Southern California Children* (Gauderman, et. al., 2000) and it subsequent update titled *Association between Air Pollution and Lung Function Growth in Southern California Children – Results from a Second Cohort* (Gauderman, et. al., 2002), provided data on the negative impacts from exposure to air pollution in the Long Beach/Los Angeles area.

This 10-year study, which began in 1993, involved twelve communities within a 200-mile radius of Los Angeles. The study subjects totaled 3,035 children and focused on fourth, seventh, and tenth graders. The children were evaluated through various pulmonary function tests (PFT). Furthermore, historical air pollution data at each respective community were also examined. The resulting statistical analysis (linear regression methods) were used to determine the association of average lung function growth rates of the respective children with the corresponding average pollution levels in those communities (Gauderman, et. al., 2000).

The results revealed a strong correlation between the PFT data with levels of particulate-matter($r=0.92$ to 0.72). The magnitude of air pollution effects in the fourth-grade cohort was greater in those that spent more time outdoors than those that spent more time indoors. A statistical example of –2.29% growth rate for an outdoor child vs. a "mostly-indoor" child of –0.15% for particulate-matter exposure were provided. The study also revealed that O_3 does not appear to have a significant impact on the PFT (Gauderman, et. al., 2000).

Though diesel exhaust particles were not specifically measured, the lung function measures on the pool of children in relation to the ambient air pollution levels were correlated with statistical significance in regards to the decrease in lung function growth. The estimated deficit in an annual growth rate of 0.9% per year of particulate-matter exposure far exceeds the 0.2% annual decrement of that of passive smoke exposure in children (Gauderman, et. al., 2000).

One of many legislative directives, Senate Bill 25, (Esuctia, SB25, 1999) enabled the Children's Environmental Health Protection Act. This law required ARB to conduct a special air quality monitoring study in the community of Wilmington, Los Angeles. This study was part of a larger statewide evaluation of the adequacy of the State's air quality monitoring network. An additional air quality monitoring unit was stationed at the Wilmington Park Elementary School. Data from this school site was compared to data from long-term air monitoring sites in the downtown Los Angeles and North Long Beach. While diesel PM was not specifically measured, pollutant characteristics from the Wilmington site did not have larger differences with the North Long Beach monitoring site. General particulate matter (PM10) were measured and found to exceed the State's 24-hour PM10 standard (50 ug/m3) on 15 occasions during the 15-month study. Differences in motor vehicle-related pollutants account for most of the differences observed between Los Angeles and Wilmington or Long Beach (ARB, 2003).

Executive Order (EO) 12898 (2/11/94) requires Federal agencies which are members of the Interagency Federal Working Group (IWG) on Environmental Justice (EJ)to identify and address, as appropriate, "disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations," and directs these Federal agencies to make EJ part of their mission. Although GSA is not a member of the IWG, EO 12898 requests that all independent Federal agencies comply with the provisions of the Order. "Environmental justice" means ensuring that low-income populations and minority populations (communities, neighborhoods, etc.) are not exposed to unjustly-that is, inequitably-high or adverse environmental impacts. Thus, the Executive Order asks agencies to identify and address any "disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations. While EO 12898 does not "create any right, benefit or trust responsibility, substantive or procedural, enforceable at law or equity by a party against the United States, its agencies, its offices, or any person," the Order interprets Federal agency responsibilities under NEPA and other environmental laws. It suggests that EJ is an aspect of civil rights, and that discrimination in the placement or location of environmentally hazardous facilities or activities may be a basis for litigation under Title VI of the Civil Rights Act of 1964 (CRA). Title VI prohibits discrimination by recipients of federal financial assistance (GSA Environmental Handbook, 1994).

California state law defines environmental justice as the fair treatment of people of all races, cultures, and incomes with respect to the development, adoption, implementation, and enforcement of environmental laws, regulations, and policies. The Board approved Environmental Justice Policies and Actions (Policies) on December 13, 2001, to establish a framework for incorporating environmental justice into the ARB's programs consistent with the directives of State law. These Policies apply to all communities in California, but recognize that environmental justice issues have been raised more in the context of low-income and minority communities. A number of specific actions support each Policy. These Policies are intended to promote the fair treatment of all Californians and cover the full spectrum of ARB activities. Underlying these Policies is the recognition to engage community members, provide the best possible information about the air they breathe and what is being done to reduce unhealthful air pollution in their communities. Through this adopted policy, the ARB has committed to working closely with all stakeholders--communities, environmental and public health organizations, industry, business owners, other agencies, and all other interested parties--to successfully implement these Policies. (EJ, 2001)

Another source which contributes to the foundation of this research project is the *Risk Reduction Plan to Reduce Particulate-matter Emissions from Diesel-Fueled Engines and Vehicles (DRRP)* (DRRP, 2000). The DRRP provided baseline statistical population and emission values for all categories of diesel-fueled engines. Specifically for this project, the DRRP estimated the 2000 statewide emissions for on-road diesel-fueled vehicles to be 7,500 tons per year. The DRRP also provided a preliminary evaluation of diesel-related retrofit technologies. These technologies range from soot type filters, oxidation type catalysts, to biodiesel fuel options. The DRRP also provided respective ranges of potential diesel PM emission reductions from the aforementioned technologies (DRRP, 2000).

The DRRP also provided the methodology for estimating ambient concentrations of particulate-matter from diesel-fueled engines and vehicles. Furthermore, the DRRP provided a series of risk characterization scenarios which estimates, through air dispersion modeling, the 70-year cancer risk associated with typical diesel-fueled engine or vehicle activity (DRRP, 2000).

The Office of Environmental Health Hazard Assessment's (OEHHA) Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments was also used. The Guidance Manual has been developed by OEHHA, in conjunction with the Air Resources Board, for use in implementing the Air Toxics Hot Spots Program (Health and Safety Code Section 44360). OEHHA is required to develop guidelines for conducting health risk assessments under the Air Toxics Hot Spots Program (Health and Safety Code Section 44360 (b) (2)). OEHHA developed four Technical Support Documents (TSDs) in response to this statutory requirement which provided the scientific basis for values used in assessing risk from exposure to facility emissions. The four TSDs describe acute Reference Exposure Levels (RELs), chronic RELs, cancer potency factors, point estimates and distributions for exposure parameters, and the general exposure assessment methodology. These TSDs underwent public and peer review, were approved by the State's Scientific Review Panel on Toxic Air Contaminants, and adopted by OEHHA for use in the Air Toxics Hot Spots program. The Guidance Manual combines the critical information from the four TSDs onto a guidance manual for the preparation of health risk assessments (OEHHA, August 2003).

The use of ARB's EMFAC 2002 data provides a scientifically approved emissions inventory. This on-road emissions inventory is an estimation of the population, activity and emissions of the on-road motor vehicles in use in California. The emissions inventory models calculate the contribution of gas, diesel, and electrically powered passenger cars, light, medium and heavy-duty trucks, motorcycles, school and transit buses and motor homes for the years 1970 through 2040. (ARB 2002).

In addition to EMFAC 2002, a study by Starcrest Consulting Group with assistance from the South Coast Air Quality Management District (SCAQMD) and the ARB, was initiated to provide data on the characteristics of the port truck fleet. The study documented license plate numbers of all the trucks that entered three terminals at the ports of Long Beach and Los Angeles during 2002. The license numbers were then cross referenced with data supplied by the California Department of Motor Vehicles (DMV) to determine the age of the vehicles. The resulting age distribution is shown in the following table (See Table 1 - Starcrest Consulting Group Survey of Truck Population and Corresponding DMV Age Distribution). Also Freeway 710 truck traffic counts from the California Department of Transportation (CalTrans) provided additional primary data (State of California Department of Transportation, November 2004).

California port operations and data pertaining to cargo / containerized movement from ports are also derived from secondary data sources from the Federal Highway Administration (Federal Highway Administration, 2005), and the Port of Long Beach (POLB, 1999). Port of Oakland operational characteristics are also used as a reference (Port of Oakland, 2005). Furthermore, pilot fleet modernization programs have been initiated to limited degrees of success through the Port of Oakland (Port of Oakland, 2005) and through Gateway Cities Clean Air Program (Gateway Cities Clean Air Program, 2002).

Primary data resulting from 151 residential surveys of the Long Beach neighborhood directly bordering the 710 freeway also contributed to the background of this project. The door-to-door survey revealed 8 cancer, 52 asthma, 44 sinusitis, 16 bronchitis, 39 shortness of breath, 59 persistent cough, 67 nasal congestion, and 87 allergy cases. Additional survey data revealed the extent of health coverage, knowledge of diesel truck traffic health impacts, and preference on how best to alleviate the negative health impacts from heavy duty diesel trucks around their neighborhood. A copy of the survey in both English and Spanish are available in Appendix A.

Research data such as the aforementioned and the identification of diesel particulate-matter as a toxic air contaminant continue to shape public health policies. Data are continuously being updated. The illustrated impact of air pollution exposure to the ultra sensitive levels of children reemphasizes the importance of the need to address localized exposure to cancerous agents.

METHODOLOGY

The hypothesis for this project states that modernizing the fleet of existing heavy-duty trucks moving containerized goods from the Port of Long Beach (POLB) with 2003 model year engines or newer by the year 2010 is feasible. The project also states that with the modernization of the truck fleet, health benefits by residents surrounding the POLB, specifically along the Freeway 710 transportation thoroughfare, will be realized. This report evaluates this hypothesis by conducting an observational study of viable technological and economic strategies for fleet modernization as well as correlating existing diesel PM emission data and health risk assessments through a health survey (see Appendix A) of a neighborhood bordering the 710 Freeway (See Appendix B).

For the purposes of this research project, the operationalizing terminology of the following terms will be defined as follow. The term diesel particulate-matter or diesel PM is defined as that portion of the exhaust from a diesel fueled compression ignition engine, which is collected via a particulate-matter sampling method. Diesel PM consists of several constituents, including: an elemental carbon fraction, a soluble organic fraction, and a sulfate fraction. The majority of diesel PM (i.e. 98%) is smaller than 10 microns in diameter (DRRP, 2000). Diesel PM is a toxic air contaminant. The term toxic air contaminant is defined as stated in the Health and Safety Code 39655 as an air pollutant which may cause or contribute to an increase in mortality or in serious illness, or which may pose a present or potential hazard to human health. The term diesel PM emission standard is the United States Environmental Protection Agency's engine emission requirement placed on specific model year on-road heavy duty diesel trucks. The standard represents the maximum amount of diesel PM allowed to be discharged from a polluting source. The term on-road heavy-duty diesel truck is defined as any commercial diesel-fueled vehicle with a gross vehicular weight rating greater than 14,000 pounds. The term realized health benefits may be best described as the reduction of cancer risk or a reduction of hospital visits due to lung related ailments. The term cancer risk is defined by a health risk assessment where risks and quantities of possible adverse health effects that may result from exposure to emissions from toxic air contaminants are identified. A health risk assessment cannot predict specific health effects; it only describes the increased possibility of adverse health effects based on the best scientific information available. The term resident is defined as those who live along (specific neighborhood as outlined on the neighborhood map in Appendix B) the 710 Freeway. The 710 Freeway is the primary route where heavy-duty diesel trucks traverse while moving freight to and from the POLB. The term containerized or TEU (twenty-foot equivalent unit) or container is defined as the generic cargo that may be transported to and from the POLB via truck or rail. The cargo may be enclosed or may be open in the case of transporting automobiles or hauling bulk raw materials such as gypsum or grain.

In 2000, the ARB stated that the statewide diesel PM emissions inventory from 687,200 on-road diesel-fueled vehicles accounted for approximately 7,500 tons of diesel PM emitted in California (DDRP, 2000). Though the data provides statewide emission levels, it does not provide geographic or site specific data. Accurate evaluation of site specific/localized emissions from heavy-duty diesel-fueled trucks may be derived from ARB's Motor Vehicle Emissions Inventory (MVEI) (ARB, 2002).

The ARB's Motor Vehicle Emissions Inventory (MVEI) provides corresponding levels of diesel PM from the on-road or specifically the on-road heavy-duty diesel truck category. Though this inventory provides data on a statewide emissions level, it also provides the methodology and emission factors enabling third party sources the means to independently calculate emissions from the MVEI's California vehicle population. The ARB has maintained this inventory, which are the product of population, activity and emissions, for over 25 years (ARB, 2002). Utilizing the MVEI methodology and the most recent traffic data from CalTrans and port truck surveys from two consulting firms have enabled an accurate up-to-date assessment of diesel PM emission levels along the 710 Freeway. Furthermore, assessing the trends of containerized imports and exports through the POLB and POLA may provide a predictor of the potential change in truck traffic along the 710. An increase in imports and exports will subsequently increase the future diesel PM emissions and corresponding local toxic exposures.

With the establishment of emissions from the port truck category, the data was used to calculate the health risk assessment. The Office of Environmental Health Hazard Assessment's (OEHHA) Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments was used (OEHHA, August 2003). Risk assessment is a complex process that requires the analysis of many variables to simulate real-world situations. There are five key variables that can impact the results of a health risk assessment for the diesel truck engine operations: 1) the amount of diesel PM emissions from the diesel truck engine operations, 2) the meteorological conditions that affect the dispersion of diesel PM in the air, 3) the inhalation rate of the receptor, 4) distance between the receptor and the emission source, 5) the duration of exposure to the diesel PM emissions. (OHEHA, August 2003).

From the aforementioned emissions data, the potential cancer health risks associated with exposure to diesel PM emissions from heavy-duty diesel vehicles operating near ports was calculated. The risk assessment for a point bordering the examined neighborhood in question along the 4,000 meter stretch of the 710 freeway was selected. The 710 freeway serves as the main thoroughfare used by port trucks when traveling to and from the ports of Long Beach and Los Angeles. The freeway, which is surrounded by residential areas, provides an extreme example of congestion and the accompanying potential health risks to surrounding communities by emissions from port trucks.

As diesel PM emission retrofit control devices are available, cost effectiveness and emission reduction benefits are also included in the feasibility assessment. As all such devices must be verified through the Diesel Emission Control Strategies Verification Program (DECSV) before entering the market, this program provided data needed for such an evaluation. The data from the DESCV also contains financially sensitive information (See Appendix E) (ARB, 2005). Costs from these retrofit devices along with costs from the used truck market provide a relative programmatic cost for any fleet modernization strategy. An economic evaluation of the heavy-duty diesel used market as well as assessing the economic profile of a truck driver operating in the containerized movement business provided additional components for determining the cost and feasibility of a fleet modernization strategy.

Also, primary health data was collected by surveying residents within the identified neighborhood bordering the 710 Freeway. Site visits were also conducted.

The surveying activities were assisted by local Environmental Justice community leaders from the "Coalition for a Safe Environment." Information from the surveys disclosed the health conditions of the residents. In addition to health related questions, the survey provided the residents choices of preferred mechanisms to implement possible cancer reducing activities.

As data collection included acquiring financial and personal information, the issue of confidentiality was addressed. Specifically, residents participating in the survey were given adequate information so an informed, voluntary decision to participate was made(O'Sullivan, et. al., 2004). The practice of informed consent maintained the ethical research practices of this project.

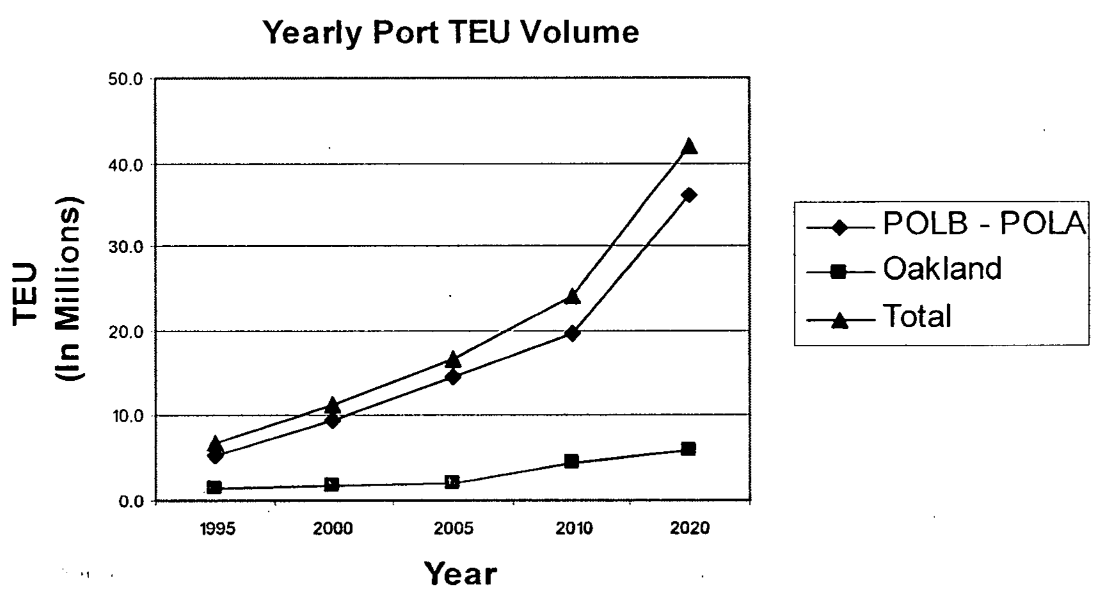
RESULTS AND FINDINGS

Container Growth / Port Operation Characteristics

California seaport import container volumes (actuals for 1995 and 2000 and projections for 2005, 2010, and 2020) are illustrated in Figure 1: Actual and Estimated Yearly Port TEU Volume 1995-2020. Between 1995 and 2000, a steady increase in container volume was recorded. The total number of TEUs (twenty-foot equivalent units or containers) for the three major ports (Los Angeles, Long Beach, and Oakland combined) increased by 4.5 million TEUs. The ports estimated container volumes are projected to increase another 5.4 million TEUs between 2000 and 2005 to a total of 16.7 million TEUs by the end of 2005. Reinforcing the accuracy of these projections is that actual container volume in 2004 was 13.1 million TEUs at Los Angeles/Long Beach and 2.0 million TEUs at Oakland, for a total of 15.1 million TEUs. TEU volumes for the period of 2005-2010 are projected to continue to increase from 7.5 million to 24.2

million TEUs (a 45 percent increase). Long term (2005 to 2020) container volume is projected to increase to approximately 25.3 million TEUs — a 152 percent increase in the 15-year period. If the projections prove to be accurate, combined container volumes for the three California seaports between 1995 and 2020 would increase by 35.2 million TEUs. (Business, Transportation and Housing Agency and California Environmental Protection Agency, 2005)

Figure 1: Estimated Yearly Port TEU Volume 1995-2020



These containers are typically transported by truck or train after being off-loaded from a ship. The method of transportation depends on variables such as the distance to the end destination and the availability of infrastructure (such as train yards). The Port of Oakland moves 100 percent of the containers from the terminals by heavy-duty diesel truck. The containers are delivered to local destinations such a nearby train yard or a distribution center. The Ports of Long Beach and Los Angeles benefit from a train yard that is located within port property. Hence, containers destined for train transportation are moved directly from the ship to the train by yard hostlers. Hostler-to-train container movement accounts for roughly 25 percent of the ports' container volume. The remaining 75 percent of the containers are transported by on-road heavy-duty trucks. 85 – 90 percent of containers are loaded and unloaded during normal hours (7am – 5pm) Monday – Friday. Of the remaining 10 - 15 percent, 5 percent of the containers are picked up on weekends and the remaining 5 – 10 percent are picked up Monday through Friday after normal business hours (POLB, 1999).

Port Trucks Characteristics

California's ports utilize between 20,000 to 40,000 trucks in the transportation of containers yearly, with the largest concentration operating at the Ports of Long Beach and Los Angeles in the South Coast Air Basin. This analysis deals exclusively with heavy-duty vehicles with a GVWR rating > 33,000 pounds. The most common vehicle configuration is that of a tractor and trailer totaling five axles. In 2002, a study by Starcrest Consulting Group with assistance from the South Coast Air Quality Management District (SCAQMD) and the ARB, was initiated to provide data on the characteristics of the port truck fleet. The study documented license plate numbers of all the trucks that entered three terminals at the ports of Long Beach and Los Angeles during 2002. The license numbers were then cross referenced with data supplied by the California Department of Motor Vehicles (DMV) to determine the age of the vehicles. The resulting age distribution is shown in the following table (See Table 1 - Starcrest Consulting Group Survey of Truck Population and Corresponding DMV Age

Distribution).

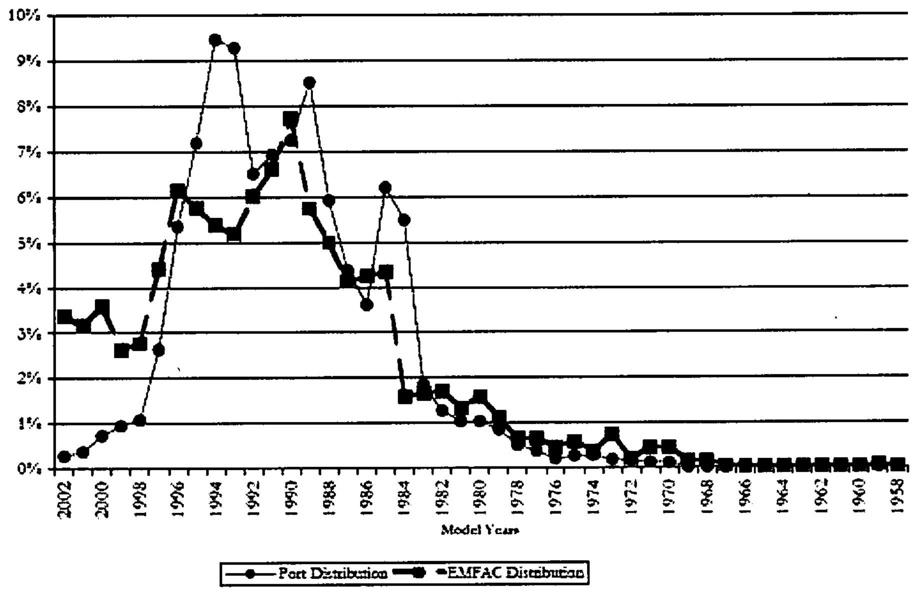
Table 1: Starcrest Consulting Group Survey of Truck Population and Corresponding DMV Age Distribution

Model Year	Number of Trucks	Percent of Population
1994-2002	2,001	28.0%
1988-1993	3,157	44.2%
1983-1987	1,537	21.5%
1970-1982	443	6.2%
Total	**7,138**	**100.0%**

The sampled population is approximately 7,200 trucks and reflects only the three terminals that took part in the survey. The total number of individual trucks operating at the ports was approximated based on the number of trips an average truck can make per day, the daily port container volume, and California Department of Transportation (Caltrans) data for annual average daily truck traffic on the California state roadway system. The total number of heavy-duty trucks operating at the ports of Los Angeles, Long Beach is estimated to be approximately 20,000. Given that the survey size of 7,138 port trucks is approximately 36 percent of the entire fleet of 20,000, it is assumed that the survey age distribution is representative of the port truck fleet as a whole. It is conceivable that depending on seasonal import/export demands that the state port truck population may fluctuate to a population closer to 40,000 trucks.

According to the analysis performed by Starcrest, the average age of the port specific truck fleet is 12.9 years as opposed to 12.2 years for the average age of ARB's EMFAC California fleet values. Thus, port trucks are approximately 0.7 years (~8 months) older then trucks in the overall California fleet (See Figure 2).

Figure 2: Port Truck Heavy-Duty Model Year Distributions (Starcrest, June 2004)



The Starcrest analysis shows that approximately 28 percent of the trucks represented in the survey are at least 16 years old (model year 1988 or older), and are equipped with older, higher PM and NOx emitting engines. Additionally, the survey also revealed that only 28 percent of the fleet may be successfully retrofitted with a diesel particulate filter (truck model year 1994 and newer).

From the analysis of the Starcrest data, the port truck age profile appears to reflect older vehicles with higher mileages. Most long-haul trucks are initially purchased and operated for 500,000–750,000 thousand miles (~5-7 years of use). After which, the trucks are sold. These used vehicles are then typically used in operations other than long haul (where newer more reliable trucks are a common practice). As most containers are hauled locally or to nearby intermodal rail facilities, a number of these used trucks are sold to independent operators to be used in such movement. A predominant characteristic of port trucks is that the trucks are configured with sleeper cabs. This may reflect from the limited availability of day cabs (trucks without an attached sleeper berth) available on the used truck market.

Driver Economic Profile

In July 1980, congress passed the Motor Carrier Act of 1980 (1980 MCA) which substantially reduced the International Chamber of Commerce (ICC) regulation of the trucking industry by permitting any carrier to establish and publish its own shipping rates(LawDog Transportation, 2000). The passage of the act resulted in a substantial increase in the number of trucking firms and competition between individual truck drivers and shipping lines. This background of events reflects the current relationship between container movement and the independent truck driver.

Under the current port/port truck dynamic, individual truck owners/operators cannot individually solicit business from a terminal. All port truck owners must contract with dispatching companies that negotiate and provide trucks to port terminals. Truck dispatch companies then in turn contract with individual port terminals to provide trucking services. Competition between dispatching companies to supply trucks to terminals is very high and contract specifics are considered confidential. Terminal / dispatcher contracts typically dictate a fixed price for each transported container. The resulting competitive bidding between dispatching companies supplying port trucks typically results in low compensation for truck drivers. Although pay scales are confidential, a $125 per local container move tends to be the average. Containers that are transported over longer distances (e.g. out-of-state) or shorter distances (e.g.

nearby intermodal train facility) may have pay scales adjusted accordingly. An indication of the marginal pay scale arose in May 2004 when 300 port truck drivers in Oakland went on strike because of diminishing profit returns in relation to the rising fuel prices. The strike was subsequently settled by agreeing to a rate increase for the truck drivers (Price, 2004).

In 2003, the South Coast Air District and the ports of Long Beach and Los Angeles initiated a fleet modernization program called Gateway Cities. A private company, TIAX, was contracted to administer the fleet modernization program. Although the program may replace any heavy-duty diesel-powered truck that operates within the geographical area, a number of port truck owners also took advantage of the replacement option within the program. The Gateway Cities program replaced approximately 180 port trucks with newer models. In the process of administering this voluntary program, TIAX collected data regarding of port truck driver economics. TIAX representatives conclude that gross yearly earnings for truck operators are approximately $40,000 - $80,000 per year. These earnings do not account for the owners cost of doing business such as fuel and maintenance. Additionally, TIAX concluded port truck operators are willing to incur only a finite amount of additional debt. To encourage port truck operators to participate in the Gateway Cities voluntary truck replacement program, TIAX structured the program so that truck operators would incur a maximum loan amount (of $5,000 - $10,000) with a maximum monthly payment of $400 - $600. Loan amounts above $15,000 or monthly payments above $600 attracted very few truck operators into the program. Typically, the replacement program would combine a loan to the operator with roughly $25,000 in grant money to cover costs (Gateway Cities Clean Air Program, 2002).

Estimated Emissions from Port Trucks

Data was used from publications: "The Port of Long Beach Baseline Emissions Inventory" (Starcrest Consulting Group, LLC , March 2004) and "The Port of Los Angeles Baseline Emissions Inventory" (Starcrest Consulting Group, LLC , June 2004) prepared by Starcrest Consulting Group to estimate emissions from trucks operating at the ports in Los Angeles and Long Beach. The Starcrest study developed a comprehensive activity based emission inventory for the ports of Los Angeles and Long Beach and improved the understanding of all port related emissions sources. The Starcrest emissions inventory developed for the Los Angeles and Long Beach ports encompass three source categories: off-road cargo handling equipment, railroad locomotives and on-road heavy-duty diesel trucks.

The HDDV emissions inventory was based on traffic modeling performed by Meyer, Mohaddes & Associates (MMA), a third party consultant. This traffic model was based on a port trip generation and regional travel demand model developed by MMA for transportation planning by the Southern California Association of Governments. The model included an activity study, interviews with the port terminal owners and operators, intersection counts, average daily truck/traffic counts, and average queue length observations. (Starcrest Consulting Group, LLC., March 2004)

Four components utilized to estimate heavy-duty diesel-fueled vehicle emissions in the report were: emissions associated with terminal travel, terminal idling, port road travel, and regional on-road travel. Terminal travel is defined as travel from a terminal gate to a container storage area. Terminal idling is idling at the terminal gate as well as idling at the container storage area. Port road travel is defined as travel outside of an individual terminal but still within the ports boundaries. Regional on-road travel is defined as travel from the edge of the port property to the truck's first localized destination. Such destinations include delivery to customers, and transloading facilities (warehouses) located throughout the Los Angeles area. (Starcrest Consulting Group, LLC., March 2004)

The traffic model developed by MMA was used by Starcrest to produce estimates of trucks volume and speed traveled over defined roadway segments (inside and outside of ports). These traffic volumes and distances were combined to produce vehicle miles traveled (VMT) which were used with speed specific EMFAC2002 emission factors to estimate driving emissions. The emissions factors, in grams per mile (g/miles), were multiplied by VMT to estimate grams of emissions, which were than converted to tons. Idling emissions were calculated based on the number of times and duration the trucks spend idling at terminal gates, and at the loading facility.

The general equation for estimating vehicle emissions is:

Equation 1 $$E = Ef*A$$

Where:

E = Emissions in grams

Ef= Emission factor in g/miles or g/hour (from EMFAC 2002)

A = Activity measure of VMT or idling in miles or hours of idling respectively

To estimate port trucks emissions, a port truck specific model year distribution developed by Starcrest with assistance from SCAQMD was utilized. Starcrest received approximately 7,200 license plate numbers of trucks operating at the ports from terminal operators in 2002. The license numbers were then cross referenced with data supplied by the California Department of Motor Vehicles (DMV) to determine the age of the vehicles or a port truck specific model year distribution (Starcrest Consulting Group, LLC., March 2004) (see Figure 2).

The port truck specific model year distribution developed by Starcrest was then used as an input to the ARB EMFAC2002 model for estimating port fleet specific emission factors, which in turn were used to calculate port truck driving and idling emissions (see equation 1). The summary of the estimated emissions for the ports of Los Angeles, Long Beach and Oakland are presented in Table 2.

Table 2: Estimated 2002 Port Truck Emissions for the Ports of Los Angeles, Long Beach and Oakland

PORT	PM (TPY)	NOx (TPY)
Port of Long Beach (POLB)	23	719
Port of Los Angeles (POLA)	24	873
Regional On-road (POLA and POLB)	56	3591
Port of Oakland (including regional on-road)	15.0	833.0
Total	**118**	**6016**

The port truck model year distribution developed by Starcrest and emission factors from EMFAC2002 to calculate port truck emissions operating at POLA and POLB were used. As Starcrest collected data on approximately 7,200 trucks, ARB staff concluded the sample was large enough to assume the survey age distribution is representative of the whole port truck fleet.

Health Risk Assessment for Heavy-Duty Diesel Vehicles Operating on Freeway I-710 near POLA and POLB

This section examines the potential cancer health risks associated with exposure to diesel PM emissions from heavy-duty diesel vehicles operating near ports. A risk assessment for a point along an arbitrary 4,000 meter stretch of the 710 freeway was chosen. The 710 freeway serves as the main thoroughfare used by port trucks when traveling to and from the ports of Long Beach and Los Angeles. The freeway, which is surrounded by residential areas, provides an extreme example of congestion and the accompanying potential health risks to surrounding communities by emissions from port trucks.

Risk assessment is a complex process that requires the analysis of many variables to simulate real-world situations. There are five key variables that can impact the results of a health risk assessment for the diesel truck engine operations: 1) the amount of diesel PM emissions from the diesel truck engine operations, 2) the meteorological conditions that affect the dispersion of diesel PM in the air, 3) the inhalation rate of the receptor, 4) distance between the receptor and the emission source, 5) the duration of exposure to the diesel PM emissions.

For the first key variable, the amount of diesel PM emissions as a function of the total diesel truck traffic, speed, and emissions per mile traveled were modeled. Meteorological conditions, the second key variable, can have a large impact on the resultant ambient concentrations of diesel PM, with higher concentrations found along the predominant wind direction and under calm wind conditions. The meteorological conditions and proximity of the receptor to the source(s) of emissions affect the concentration of the diesel PM in the air where the receptor is located. The Long Beach (1981) meteorological data with urban dispersion coefficients was used. In addition, the exposure duration and inhalation rates are key factors in determining potential risk, with longer exposure times and higher inhalation rates typically resulting in higher estimated risk levels. For this analysis it was assumed that an adult 70 year exposure duration and inhalation rate of 302 liters/Kg-day, as recommended for estimating health impacts in the current OEHHA guidelines, was used (OEHHA, 2003).

The fourth variable, distance between the receptor and the emission source, is illustrated in Figure 1 below. CalTrans provided specific measurements for an emissions source along the 710 freeway, post mile 11.5, at north of Del Amo Boulevard, and truck count by hour (Figure 3). The data also included the inside shoulder width, outside shoulder width, number of lanes, median width, and the width of the 710. Additionally, truck speed, lane usage, traveling time per lane of 60 percent, 30 percent and 10 percent for lanes 1, 2, and 3 respectively and emission factors were also used in modeling of the risk (Figure 4).

Figure 3: HHDV Counts vs. Diurnal Variation for Freeway 710

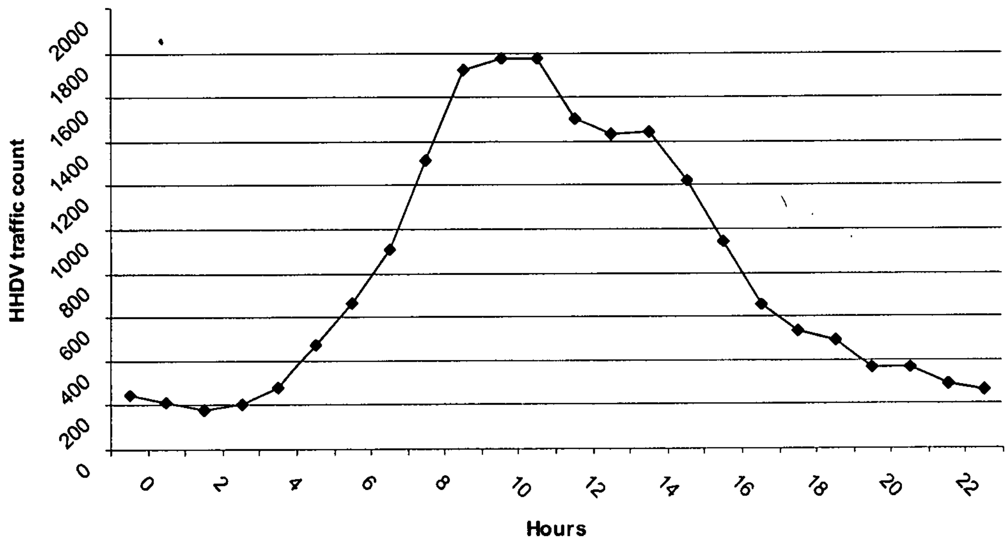
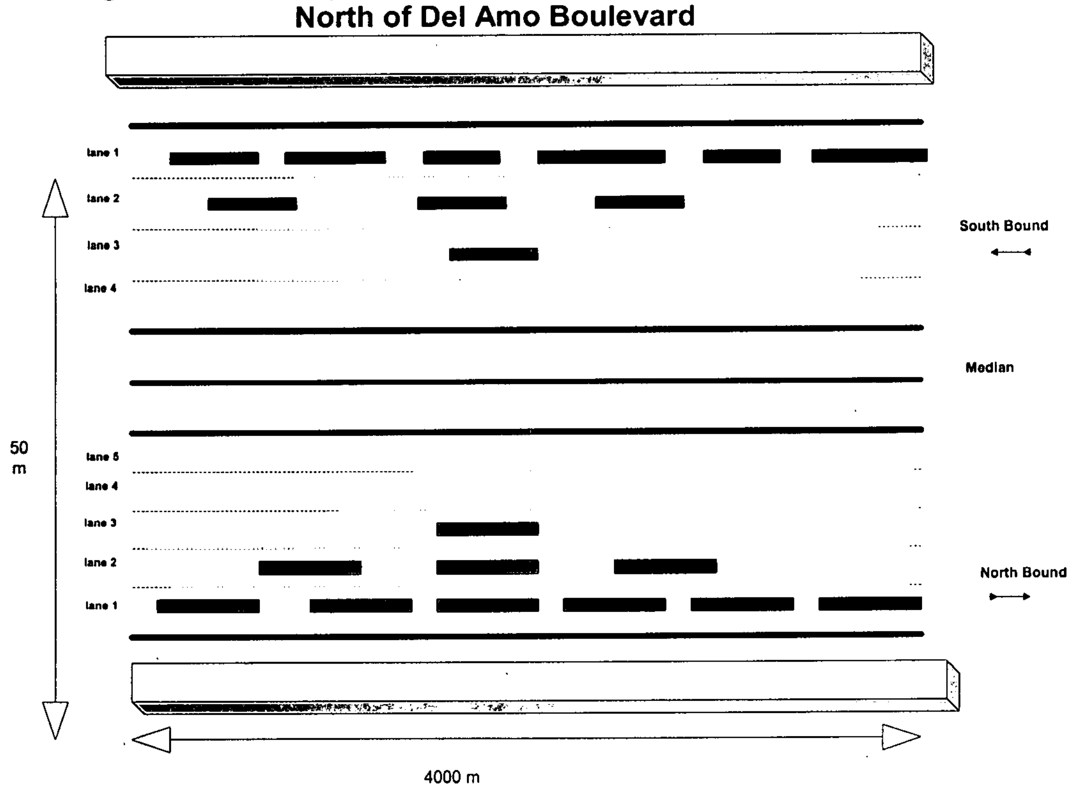


Figure 4: Arbitrary segment of Freeway 710,post mile 11.5, North of Del Amo Boulevard



The risk estimates show the relative magnitude of potential cancer risk based on total truck traffic. These results can be used to give a general indication of the potential risk at particular locations, however, a site-specific analysis would be needed to fairly represent the cancer risk at a specific location.

For heavy-duty diesel-fueled vehicles operating near the ports, the receptors that are likely to be exposed include residents located near the port or the main traffic routs into and out of the port. Exposure was evaluated for diesel particulate via the breathing or inhalation pathway only. The magnitude of exposure was assessed through the following process. Emission rates were developed using emission parameters determined from site visits, from Starcrest's port truck population distribution survey, and ARB's EMFAC2002 emission's model. During the site visits, other information such as physical dimensions of the source, operation schedules, and receptor locations were obtained. Computer air dispersion modeling (CAL3QHCR) was used to provide downwind ground-level concentrations of the diesel PM at near-source locations. Meteorological data is Long Beach (1981) with urban dispersion coefficients was selected to evaluate meteorological conditions with lower wind speeds, which result in less pollutant dispersion and higher estimated ambient concentrations.

Figure 5 shows the potential cancer risks to nearby receptors between 25 to 6400 meters from the center of the source of emissions. The two curves represent risks one the west side and the east side of the freeway. The west side shows a slight reduction in risk compared to the east side due to eastwardly wind conditions.

Figure 5: Potential Cancer Health Impacts

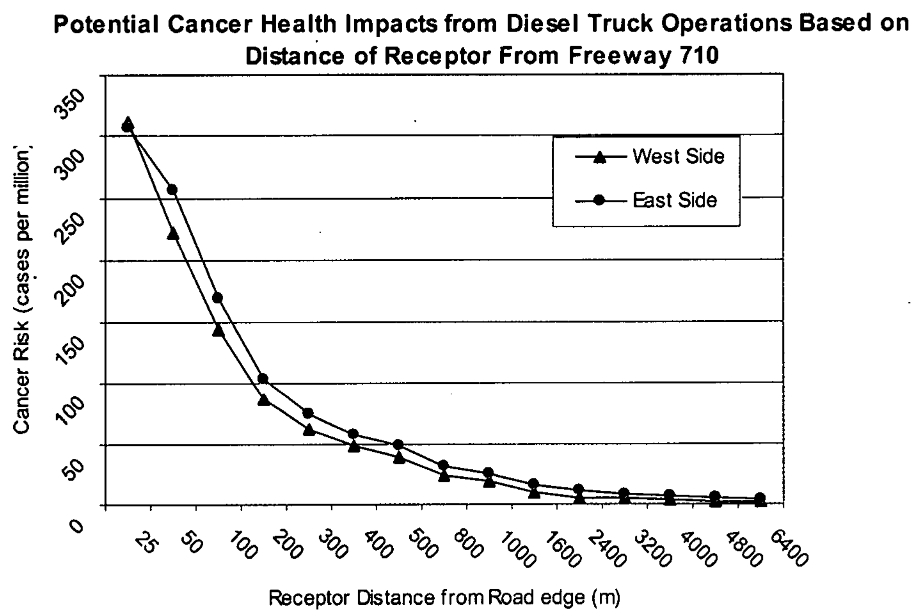
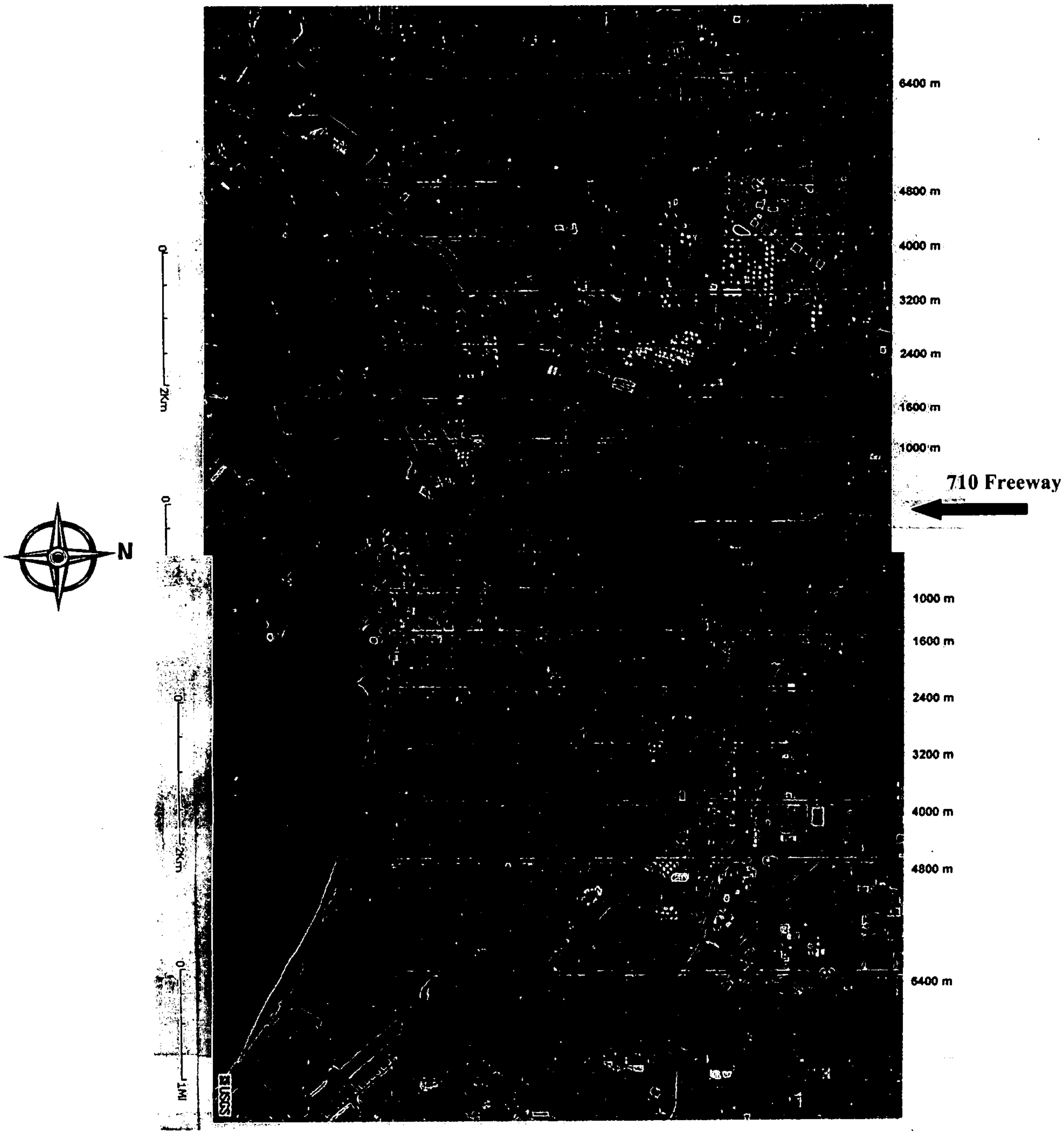


Figure 3 assumptions:

- The total width of I-710 freeway is 50 meters, and an arbitrary segment length of 4000 meters is considered
- Each direction has three lanes (most outside lanes) for HDDV traveling. In reality there are five lanes in North bound and 4 lanes in South bound.
- Emission factor used for diesel PM is 0.293 grams/vehicle-mile.

Figure 6 below shows an aerial view of the immediate area surrounding the Port of Long Beach. The coordinates of the emission source were plotted and superimposed on a GIS map. This map shows neighborhoods that may be affected by port truck traffic. The potential cancer health impacts for diesel truck operations based on the distance from freeway 710 are also shown.

Figure 6: Aerial Photo of Port of Long Beach – GIS Map



GIS map procured from:
http://terraserver.homeadvisor.msn.com/image.aspx?T=4&S=14&Z=11&X=121&Y=1168&W=1

The estimated potential cancer risk is based on a number of assumptions (detailed above); actual risks to individuals may be less than or greater than those presented here. For example, increasing the truck traffic would increase the potential risk levels. Decreasing the exposure duration or increasing the distance from the source to the receptor location would decrease the potential risk levels. The estimated risk levels would also decrease over time as lower-emitting diesel engines become more common within the fleet. As stated above, the results presented are generic in nature and not directly applicable to any particular location. Rather, this information is intended to provide an indication of the potential relative levels of risk that may be observed from diesel truck operations on freeway 710.

Diesel PM is not only a lung cancer hazard but also a hazard for non-cancer respiratory effects such as pulmonary inflammation, asthma. Because of their small size, the diesel PM particles can be inhaled easily and effectively reach the inner sections of the lungs along with compounds on the surface of PM (DRRP, 2000). Both the State of California and the U.S. EPA have established standards for the amount of PM_{10} and $PM_{2.5}$ in the ambient air. These standards define the maximum amount of particles that can be present in outdoor air without threatening the public's health and welfare. A number of variables can have significant impacts on exposure. These include emission estimates, meteorological conditions, and exposure duration. The key variables in estimating exposure are proximity to the emission source, and exposure duration. The longer the duration of exposure, the greater the health risk to the individual. A significant effect of exposure to diesel PM emissions is an increase of hospitalization due to asthma attacks. To maximize PM emission reductions, a fleet modernization strategy to replace all trucks that cannot be retrofitted with a level three PM emission control technology and retrofit all trucks that are eligible with a level three PM emission control technology was investigated. The estimated port truck PM emission reduction after full implementation is 100 tons per year (tpy). Based on the methodology used in all Diesel Air Toxic Control Measures (ATCM), 0.59 tons per year (tpy) of diesel PM is associated with one asthma attack. Hence the associated emission reduction of 100 tpy of diesel PM could potentially reduce 169 asthma attacks per year.

<u>Residential Surveys</u>

From February 17 through March 4, 2006, residents of the observed neighborhood (See Appendix B) were surveyed via door-to-door (See Appendix A). Residents from 151 unique households responded. From the 151 responses, data from 250 adult males, 278 adult females, and 135 children were compiled. Though the demographics relay an average household occupancy of approximately 4, the range of occupancy was from 1 to 11 per household. Though not directly asked (surveyors annotated an observational determination), of the 119 annotated observations, the composition of race was the following:

- 40% Hispanic
- 33% Asian
- 14% White
- 13% African American

Also on average, the respondents have lived at their respective homes for approximately 13 years.

The survey also provided health data. 75% or 112 households annotated that they had some type of health coverage. 24% or 31 annotated that they did not have any health coverage and 5% or 8 declined to state. Data from the survey also provided a relative count of air related ailments. The data revealed 8 cancer, 52 asthma, 44 sinusitis, 16 bronchitis, 39 shortness of breath, 59 persistent cough, 67 nasal congestion, and 87 allergy cases.

From those surveyed, all stated that they had knowledge of the negative health impacts of the diesel trucks driving on the 710. Many residents also pointed out another source of heavy-duty diesel port truck traffic on the western side of the neighborhood. The terminal island freeway or freeway 103 was then observed to have both diesel truck traffic as well as locomotive activity.

When respondents were provided several options to rank in order of preference the means to fund a clean up effort of the diesel trucks in the area, the responses were as follows.

• Retail / Distributor Store Tax	38%
• Port Container Fee	33%
• Truck Tax	19%
• Fuel Tax	6%
• State Tax	4%

Though the survey also revealed that over 90% believed that industries that pollute should contribute more to the cost of health care, they elected not to potentially penalize the source of the emissions, the diesel truck. Rather, the overriding perception that the retailers and large distributors of goods should bear the brunt of responsibility of cleaning up the trucks was noted. This perception also reflects towards the application of a port container fee. The visual observations of witnessing the countless containers being hauled to and from the ports in the vicinity of their homes has elevated this category as another funding source.

Fleet Modernizing Strategies for Port Trucks

Two general strategies which include respective potential costs and emission benefits were developed. The estimated cost effectiveness methodology is discussed in detail in Appendix C. Also, the following analysis for each strategy is intended as a general over-view for comparative purposes only. The methodology/calculations of each strategy are also discussed in Appendix C. It is possible, with continued investigations, the best strategy chosen may vary significantly from the examples below.

Both strategies assume a fleet of 20,000-40,000 port trucks collectively generate baseline emissions of 118 tons/year PM and 6,016 tons/year NOx. The emission reduction calculation methodology is discussed in Appendix D. Also, all strategies assume that by 2010, the entire fleet operating at ports will be modernized. Enforcement is envisioned to be primarily through the local air districts and ports. Each terminal will be responsible for ensuring only compliant vehicles are allowed to conduct container transportation operations after 2009.

Strategy #1: Replacement of 1993 MY and Older Trucks with Reflashed 1994 to 1998 MY trucks with Diesel Particulate Filters (DPFs)

This strategy will reduce both NOx and diesel PM emissions by replacing model year 1993 and older trucks with newer 1994 to 1998 model year trucks. The use/installation of diesel particulate filters will reduce diesel PM emissions by approximately 85 percent and are widely available for installation on model year 1994 and later trucks. The program's implementation start date of 2007 will allow time for the ultra-low sulfur diesel needed by particulate filters to become universally available (currently mid 2006). ARB staff chose model year 1998 trucks as the end point to correspond to the last year of the 1994-1998 NOx standard (see Appendix D, Table D-2).

All trucks operating at the ports (both replacement trucks and non-replaced trucks) will be required to install a diesel particulate filter that will achieve an 85 percent (level 3) PM reduction. The overall diesel PM reduction for the fleet will be approximately 100 tons/year (~85 percent reduction). Additionally, replacing older, higher NOx emitting trucks with newer model year 1994-1998 trucks will generate fleet wide NOx reductions of approximately 963 tons/year (~16 percent reduction).

This strategy provides the most fiscally economical approach due to the age and replacement cost of the trucks, but achieves the least in NOx reductions (PM reductions are the same for both strategies). As the replacement vehicles are built to a NOx engine standard lower than current model year trucks, this strategy provides the smallest NOx reduction. This strategy will potentially replace approximately 14,000 – 28,000 port trucks older than 1994 with 1994-1998 vehicles.

Costs, while significant, are less compared to the other strategy. The overall cost of this strategy is estimated to be approximately \$380 million - \$390 million. The cost effectiveness is estimated to be in the range from \$29,500 - \$31,000 per ton of pollutant reduced. A detailed cost analysis is provided in Appendix C. This strategy is also expected to result in local and overall statewide reduction in the health risk associated with emissions of diesel PM and NOx by the port specific fleet.

Strategy #2: Replacement of 2002 MY and Older Trucks with 2003 MY Trucks (NOx Engine Standard 2.5g/bhp-h) and Installation of DPF on All Trucks

This strategy will reduce both NOx and diesel PM emissions by replacing model year 2002 and older trucks with newer 2003 or more recent model year trucks. Diesel particulate filters will again reduce diesel PM emissions by approximately 85 percent. The programs implementation start date of 2007 will allow time for the ultra-low sulfur diesel needed by particulate filters to become universally available (currently mid 2006). Again, model year 2003 and later trucks were chosen to correspond to the 2003 NOx engine standard of 2.5g/bhp-h.

All trucks operating at the ports (both replacement trucks and non-replaced trucks) will be required to install a diesel particulate filter that will achieve an 85 percent (level 3) PM reduction. The overall diesel PM reduction for the fleet will be approximately 100 tons/year (~72 percent reduction). Additionally, replacing older, higher NOx emitting trucks with newer model year 2003 trucks will generate fleet wide NOx reductions of approximately 3,862 tons/year (~64 percent reduction).

This strategy requires more fiscal expenditures than the first. However, this strategy achieves a higher NOx reduction by replacing 20,000 – 40,000 port trucks older than 2003 with 2003 or newer vehicles. This strategy provides approximately 4.5 times the NOx reduction compared to the first strategy because replacement vehicles are built to a NOx engine standard of 2.5g/bhp-h, which is significantly lower than the 2002 and older model year truck NOx engine standard of at least 4g/bhp/h.

The overall cost of this strategy is estimated to be approximately $897 million to $966 million. The cost effectiveness is estimated to range from $25,000 - $51,000 per ton of pollutant reduced. A detailed cost analysis is provided in Appendix C. It is expected that there will be a local and overall statewide reduction in the health risk resulting from reduced emissions of diesel PM and NOx by the port specific fleet.

SUMMARY AND CONCLUSION

This research project evaluated the feasibility of modernization the heavy-duty diesel trucks transporting containerized goods in the POLB region. The outcome of modernizing this fleet provides realized health benefits to the surrounding communities. The existing emissions levels from port trucks in the POLB area contribute approximately 118 tons/year of diesel PM to the surrounding communities. The corresponding health risk levels on a calculated level appear to under represent those of actual levels when compared on equal population scales. Though a direct causality may not necessarily be determined from this research, there is enough statistical and health data to provide a strong correlation of the negative health impacts of diesel PM from this localized source of diesel trucks.

The determination of the cost effective and emission reducing strategies that will accomplish the modernization of the fleet by 2010 while achieving a reduction of cancer risk has been calculated. The diesel PM emission reductions of 100 tpy of diesel PM could potentially reduce 169 asthma attacks per year as well as greatly reduce the cancer risk from this source. While both fleet modernization strategies initially provide a significant investment, the mechanism for supporting such an endeavor is present. Considering the cost range for both strategies is from $356 to $966 million, the average projected costs (20,000 qualifying vehicles) were found to be $4 - $11 per TEU container shipped per year for four years. This cost may be further reduced by sharing this fee between both POLB and the retailer/distributor.

Through the door-to-door survey of the impacted neighborhood, clear support for not only an accelerated fleet modernization strategy, but acceptable funding mechanisms were also identified. As the respondents revealed economic concerns for the truck driver, the preference of the port container fee and retail/distributor tax became attractive. As the economic profile of a port truck driver revealed a limited ability to modernize their respective vehicle, strict mandatory/regulatory requirements may negatively impact this sector of trucking business.

Despite overwhelming scientific evidence of the negative health impacts of diesel PM, action from regulatory and business entities to address this localized issue does not appear to be forthcoming. It is recommended that continued studies on a neighborhood scale should be implemented. A "snap-shot" of the health of a neighborhood does not provide the impact of historical health trends. Individual people studies continue to provide invaluable data. However, historical neighborhood scaled studies must be integrated in future studies. Additional supportive data will encourage local policy makers to fully address the localized impacts of their constituents.

With the validation of this research project's hypothesis may provide a mechanism to address similar localized exposures. Other areas similar to this situation include other ports and residential areas surrounding major distribution centers or warehouses. Such activities may be able to utilize similar approaches described in this research project or provide opportunities for a new hypothesis. Regardless, it is recommended that city planning procedures not only fully incorporate health risk studies, but also strongly weigh such findings and projections to the benefit of the public. It is also recommended that cities reassess and update all residential regions with health risk impacts. It is an inherent responsibility for all public agencies to represent the public's best interest.

REFERENCES

AB 1009 Pavley. (2004). Approved and Filed September 29, 2004. Air Pollution: Heavy-duty Vehicles emissions. http://www.arb.ca.gov/msprog/hdvip/bip/ab1009.pdf

AB 2650, Lowenthal. (2002) Approved and Filed September 30, 2002. Air Pollution: diesel emissions: California Port Community Air Quality Program: Bay Area Air Quality Management District and South Coast Air Quality Management District. http://www.leginfo.ca.gov/pub/01-02/bill/asm/ab_2601-2650/ab_2650_bill_20020930_chaptered.pdf

ARB 1999. (1999). California Air Resources Board Informational Package for the Heavy-Duty Vehicle Inspection Program, Periodic Smoke Inspection Program. Mobile Source Operations Division, Mobile Source Enforcement Branch. http://www.arb.ca.gov/msprog/hdvip/hdvip.htm

ARB 2002. (2002). California Air Resources Board EMFAC2002 Model

ARB 2003. (2003). California Air Resources Board Staff Report Proposed Control Measure for Diesel Particulate Matter from On-road Heavy-Duty Diesel-Fueled Residential and Commercial Solid Waste Collection Vehicle Diesel Engines. California Air Resources Board. 2003. http://www.arb.ca.gov/toxics/idling/idling.htm

ARB. (August 2003). Proposed 2003 State and Federal Strategy for the California State Implementation Plan. California Air Resources Board. August 2003.

ARB 2004. (2004). California Air Resources Board Staff Report Airborne Toxic Control Measure to limit Diesel-Fueled Commercial Motor Vehicle Idling. California Air Resources Board. 2004 http://www.arb.ca.gov/toxics/idling/idling.htm

ARB 2005. (2005). California Air Resources Board Diesel Emission Control Strategies Verification Level 3, Level 2 and Level 1 verified Technologies. California Air Resources Board. 2005. www.arb.ca.gov/diesel/verdev/verdev.htm

ARB 2005. (January 2005). Ports and Air Quality Briefing Paper. Prepared for Chairman Alan Lloyd, January 2005.

ARB 2005. (July 2005). On-Board Diagnostic Requirement for Big Rigs. California Air Resources Board. July 21, 2005 www.arb.ca.gov/newsrel/nr072105.htm

ARB Research Department, 2005. Recommended discount rate for Capital Projects. http://www.arb.ca.gov/regact/trude03/trude03.htm

Avol, Edward, Gauderman, James W., Tan, Sylvia M., London, Stephanie J., and Peters, John M. (2001). Respitory Effects of Relocating to Areas of Differing Air Pollution Levels. American Journal of Respiratory and Critical Care Medicine, 164: Page 2067-2072.

Business, Transportation and Housing Agency and California Environmental Protection Agency. (2005). Goods Movement Action Plan – Phase I: Foundations. Business, Transportation and Housing Agency and California Environmental Protection Agency. September 2005. http://www.arb.ca.gov/gmp/gmp.htm

CalTrans (2004). Annual Average Daily Truck Traffic on the California State Highway System. CalTrans. 2004

Carl Moyer Program, 2005. Proposed Project Criteria (August 2005). Presented at Sacramento Public Workshop, http://www.arb.ca.gov/msprog/moyer/moyer.htm

Cleaire / Cummins Westport, 2005. Cost Estimates for 2005 DPF/NOx and DOC Products, Installation, & Annual Service/Maintenance Requirements, Information Provided by Rick Jesse, Territory Manager, by telephone conversation with ARB staff on September 14, 2005.

Clean Diesel Technology. (2005). Cost Estimates for 2005 FTF/FBC, DPF/FBC, and DOC/FBC Products, Installation, & Annual Service/Maintenance Requirements, Information Provided by James Valentine and Glenn Reid, by telephone conversation with ARB staff on April 18, 2005, and on September 13 & 14, 2005.

Cummins Westport. 2005. http://www.cumminswestport.com

DECS. (2003) California Air Resources Board Rule Making on the Adoption of the Diesel Emission Control Strategy Verification Procedure, Warranty and In-use Compliance Requirements for On-road, Off-road, and Stationary Diesel-Fueled Vehicles and Equipment. California Air Resources Board. 2003. Available: http://www.arb.ca.gov/diesel/verdev/verdev.htm

DRRP (2000). Air Resources Board's Risk Reduction Plan to Reduce Particulate-matter Emissions from Diesel-Fueled Engines and Vehicles. California Air Resources Board. October 2000.

EJ. Environmental Justice Communities Listing. California Air Resources Board. 2003.

EJ (2003). Environmental Policies and Actions. California Air Resources Board. 2001 http://www.arb.ca.gov/ch/programs/ej/ejpolicies.pdf

GSA Environmental Handbook (1994) http://www.gsa.ene.com/Nepa/envbook/page36.htm

Emissions Standards Reference Guide for Heavy-Duty and Non-Road Engines: EPA420-F-97-014, September 1997.

Federal Highway Administration. (2005). Freight Trends/Issues, Multimodal System Flows and Forecasts, and Policy Implications. Federal Department of Highway Administration. 2005.

Fleetgaurd Emissions Solutions, 2005. Cost Estimates for 2005 DPF and DOC Products, Installation, & Annual Service/Maintenance Requirements, Information Provided by Amy Boerger, Retrofit Business Leader, by telephone conversation with ARB staff on September 14, 2005.

Gateway Cities Clean Air Program. (2002). Clean Air Program Guidelines. http://www.cleanerairpartnership.org/ledge.html

Gauderman, James W., Gilliland, Frank G., Vora, Hita, Avol, Edward, Stram, Daniel, McConnel, Rob, Thomas, Duncan, Lurmann, Fred, Margoli, Helene G., Rappaport, Edward B., Berhane, Kiros, and Peters, John M. (2000). Association between Air Pollution and Lung Function Growth in Southern California Children. American Journal of Respiratory and Critical Care Medicine, 162: 1383-1390, 2000.

Gauderman, James W., Gilliland, Frank G., Vora, Hita, Avol, Edward, Stram, Daniel, McConnel, Rob, Thomas, Duncan, Lurmann, Fred, Margoli, Helene G., Rappaport, Edward B., Berhane, Kiros, and Peters, John M. (2002). Association between Air Pollution and Lung Function Growth in Southern California Children – Results from a Second Cohort. American Journal of Respiratory and Critical Care Medicine, 166: Page 76-84.

LawDog Transportation (2000). History of Trucking Regulation at LawDog© - "Partial Deregulation", 1996-2000. http://www.lawdog.com/transport/tp1.htm

Hotspots Analysis Reporting Program (2003). California Air Resources Board. Available: http://www.arb.ca.gov/toxics/harp/harp.htm

Ironman Parts & Service (2005). Cost Estimates for 2005 DPF and DOC Products, Installation, & Annual Service/Maintenance Requirements, Information Provided by Monica George, Technical Sales, by telephone conversation on September 2 &15, 2005.

Manufacturers of Emission Controls Association, May 2004. Briefing on Recent Emission Control Technology Developments

Meyer, Mohaddas, & Associates. www.iteris.com

Mobile Source Emissions Inventory Program (2005). California Air Resources Board. http://www.arb.ca.gov/msei/msei.htm

Moyer. (2003). The Carl Moyer Memorial Air Quality Standards Attainment Program Guidelines. California Air Resources Board, 2003.

Office of Environmental Health Hazard Assessment (OEHHA, August 2003). The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments. www.oehha.ca.gov/air/hot_spots/HRSguide.html

O'Sullivan, Elizabethann, Rassel, Gary R., and Berner Maureen (2003). Research Methods for Public Adminstrators. Addison Wesley Longman, Inc. 2003.

Peters, John M., Avol, Edward, Gauderman, James W., Linn, William S., Navidi, William, London, Stephanie J., Margolis, Helene, Rappaport, Edward, Vora, Hita, Gong, Henry, and Thomas, Duncan C. (1999). A Study of Twelve Southern California Communities with Differing Levels and Types of Air Pollution – II. Effects on Pulmonary Function. American Journal of Respiratory and Critical Care Medicine, 159: Page 768-775.

POLB (1999). The Port of Long Beach Economic Impacts – Contributing to the Local, State, & National Economies. The Port of Long Beach. 1999.

Pope, Arden C., Burnett, Richard T., Thun, Michael J., Calle, Eugenia E., Krewski, Daniel, Ito, Kazuhiko, and Thurston, George D. (2002). Lung Cancer, Cardiopulmonary Mortality, and Long-term Exposure to Fine Particulate Air Pollution. Journal of American Medical Association. 287: Page 1132-1141.

Port of Oakland. (2005). Truck Air Quality Program www.portofoakland.com/environm/prog_06.asp

Price, Tom. (2004). High costs, low pay spark port truckers action. International Longshore and Warehouse Union. July 2004. http://ilwu.nisgroup.com/dispatcher/2004/05/truckers-action.cfm

Sacramento Emergency Clean Air and Transportation, 2005. www.4secat.com

Sacramento Metropolitan Air Quality Management District (SMAQMD):
Rule 1003 – Reduced-Emission Fleet Vehicles/Alternative Fuels. Adopted 7/19/94.
http://www.arb.ca.gov/drdb/sac/curhtml/r1003.htm

SB 1265: http://www.theorator.com/bills109/s1265.html

School Bus Idling ATCM
http://www.arb.ca.gov/toxics/sbidling/sbidling.htm

Shore, Teri. (2004). Project Description: Shore side power for new cruise ship terminals. Bluewater Network.

South Coast Air Quality Management District (SCAQMD):
Rule 1186.1 – Less-Polluting Sweepers. Adopted 9/18/00
http://www.arb.ca.gov/drdb/sc/curhtml/r1186-1.htm

South Coast Air Quality Management District (SCAQMD):
Rule 1195 – Clean On-Road School Buses. Adopted 4/20/01
http://www.arb.ca.gov/drdb/sc/curhtml/r1195.pdf

South Coast Air Quality Management District (SCAQMD):
Rule 1196 – Clean On-Road Heavy-Duty Public Fleet Vehicles. Adopted 10/20/00.
http://www.arb.ca.gov/drdb/sc/curhtml/r1196.htm

Staff Report: Initial Statement of Reasons for Proposed Rulemaking: Airborne Toxic Control Measure to Limit Diesel-Fueled Commercial Motor Vehicle Idling. California Air Resources Board. July 2004.

Starcrest Consulting Group, LLC. (June 2004). The Port of Los Angeles Final Draft Port-wide Emissions Inventory. Starcrest Consulting Group, LLC. June 2004.

Starcrest Consulting Group, LLC. (March 2004). The Port of Long Beach Baseline Emissions Inventory. Starcrest Consulting Group, LLC. March 2004.

State of California Department of Transportation. (November 2004). Annual Average Daily Truck Traffic on the California State Highway System. State of California Department of Transportation. November 2004.

The California Diesel Fuel Regulations: August 14, 2004.
http://www.arb.ca.gov/fuels/diesel/081404dslregs.pdf

U.S. EPA. (2005). SmartWay Transport Partnership. www.epa.gov/smartways/swplan.htm

U.S. EPA's 2007 Final Rule on the Control of Emissions of Air Pollution from 2007 and Later Model Year Heavy-Duty Engines and Vehicles: Referred to as U.S. EPA's 2007 Final Rule or 2007 Final Rule, EPA420-F-05-021, June 21, 2005.

United States Department of Transportation – Federal Highway Administration (2004). Freight Transportation – Improvements and the Economy. FHWA-HOP-04-005. June 2004.

Voluntary Retrofit Program: "Use of Urban Bus Program Retrofit/Rebuild Equipment and Third Party Verification System and Model State Policies for the Retrofit/Rebuild of Heavy-duty Diesel Engines" (PDF, 97 pages, 690K) (EPA420-R-99-014, June 1999)

Voluntary Software Upgrade Program http://www.arb.ca.gov/msprog/hdsoftware/volprog.pdf

West Coast Diesel Emissions Reductions Collaborative. (2005). West Coast Collaborative fact sheet. http://www.westcoastdiesel.org/files/outreach/Collaborative

APPENDIX A

Residential Health Survey

This form is to be completed by the head of the household.

1. Including yourself, how many people live at this residence?

#		Ages
	Males	
	Females	
	Children	

2. Of those residing in your home, how many are diagnosed to have or currently experiencing (you may count for multiple symptoms):

_________ Cancer Type _______________ Allergy _______________
_________ Asthma Bronchitis _______________
_________ Persistent Coughing Sinusitis _______________
_________ Shortness of breath Nasal Congestion _______________

3. Last year, of those with any of the above conditions, how many times a year did they see a doctor (total of the group)? Emergency visits _________ Regular check ups ______________
4. How many that reside in your home have health insurance? _________
5. What type of medical health insurance? ______________________________________
6. How many days of work were missed last year due to the above illness(es)? _________
7. How many days of school were missed last year due to the above illness(es)? _________
8. Is anyone taking any health prescription medication for the health problems?____ Yes ____ No
   What types?____
9. Is anyone taking over-the-counter non-prescription medicine? ___ Yes ___ No
   What types?____
10. How long have you lived at your present address? _________ In Long Beach ? _________
11. Are you aware of the health impacts of diesel trucks traveling along Long Beach 710 Freeway?

______ No ______ Yes If Yes, how did you become aware? Check all that apply.

_________ TV _________ Friend
_________ Radio _________ Doctor
_________ Newspaper _________ Nurse
_________ Magazine _________ Organization

If No, would you like to receive additional public health information? Yes ___ No___

12. If a proposal to reduce air pollution (health problems) from diesel trucks traveling along the Long Beach 710 Freeway was available, what mechanism would you prefer? (Rank – 1, 2, 3, etc.)

___ New Law Initiative — Ask your elected representative to make a law that cleans up air pollution from diesel trucks

___ Statewide tax — Everyone living in California would pay for cleaner trucks in your community and future growth areas

___ Port container fee — Every container transported from the Port of Long Beach and Los Angeles would be charged a fee to pay for cleaner trucks that travel through your neighborhood

___ Truck tax — Every diesel truck in California would be taxed to pay for cleaner trucks in your neighborhood and future areas

___ Increase fuel tax — Diesel fuel sold in California would be taxed higher to pay for cleaner diesel trucks

___ Retail/Store/Distributor Tax — A shipping fee/tax would be charged to the retail/store/distributor of the goods being delivered

13. Do you feel that business and shipping (ships, trains, trucks) industries that pollute and contribute to public health problems should pay for public health care? ____ Yes ____ No
14. Do you believe that California should invest in new alternative non-polluting transportation and intermodal container system technologies? ____ Yes _____ No

Encuesta de Salud Para Residentes

Esta forma tiene que ser cumplida por el Señor o Señora de la casa.

1. Con usted incluido, cuantas personas viven en su alojamiento?

#		Edad
	Masculinos	
	Femeninos	
	Niños	

2. De la gente que vive en su alojamiento, cuantas personas había diagnosticado o sufren del: (se puede marcar mas que uno):

_________ Cáncer Tipo _____________ Alergia _______________
_________ Asma Broncitos _______________
_________ tos persistente Sinusitis _______________
_________ dificultades de respiración Congestión nasal _______________

3. De los miembros de su familia que habían diagnosticado con las enfermedades de que usted mencionó, cuantas veces por año visitan el medico? Visitas del emergencia ________ Visitas regulares ____________
4. Cuantas personas en tu alojamiento tiene seguro de salud? ________
5. Que tipo de seguro de medicina tiene(n)? ____
6. Cuantas días por año tenían que faltar trabajo por la culpa de enfermedad que usted mencionó? ________
7. Cuantas días por año tenían que faltar de escuela por la enfermedad que usted mencionó?________
8. De la gente que esta enferma están tomando algunos remedios para su problema de salud?____ Si ____ No
   Que remedios?_____
9. Alguien esta tomando remedies que compro en la farmacia sin la consulta del medico? ___ Si ___ No
   Que remedio?____
10. Hace cuando esta viviendo en este alojamiento? ________ En Long Beach ? _______
11. Esta conciente usted que los camiones diesel que pasan por la ruta 710 tienen impactos de salud para los residentes de esta zona? _____ No _____ Si Si contestó si, como usted sabe de los impactos? (se puede marcar mas que uno):

_________ Televisión _________ Amigos
_________ Radio _________ Medico
_________ Diario _________ Organización
_________ Revistas

Si No, quiere usted recibir información de la salud publica? Si ___ No___

12. Si había una posibilidad para eliminar emisión de los camiones diesel que contaminan por la ruta 710, que preferencia usted tendrían? (Marca dependiente de la importancia 1, 2, 3, etc.)

___ Nueva Ley — Pedir su representante para hacer un ley que elimina contaminación de los camiones

___ **Impuestos del estado** — **Todos en California tendrían que pagar un impuesto para limpiar el contaminación de los camiones en su zona y en todas zonas contaminadas.**

___ **Impuesto del container** — **Por cada container que transportan del puerto de Long Beach y Los Ángeles** tendrían que pagar $5 a cada camión que pasa por su barrio.

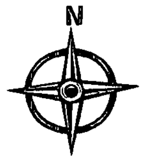
___ Impuesto de Camión — Todos camiones diesel en California tendrían que pagar un impuesto para eliminar contaminación de sus camiones que pasan por su barrio.

___ Aumento de los impuestos de la gasolina — Gasolina que esta vendido en California tendría un impuesto mas alto para pagar la eliminación de contaminación de los camiones diesel que pasan por su barrio.

___ Impuesto de vedadores/ Distribudores/ negocios — Un impuesto para ventadores o distributores de las cosas comerciales.

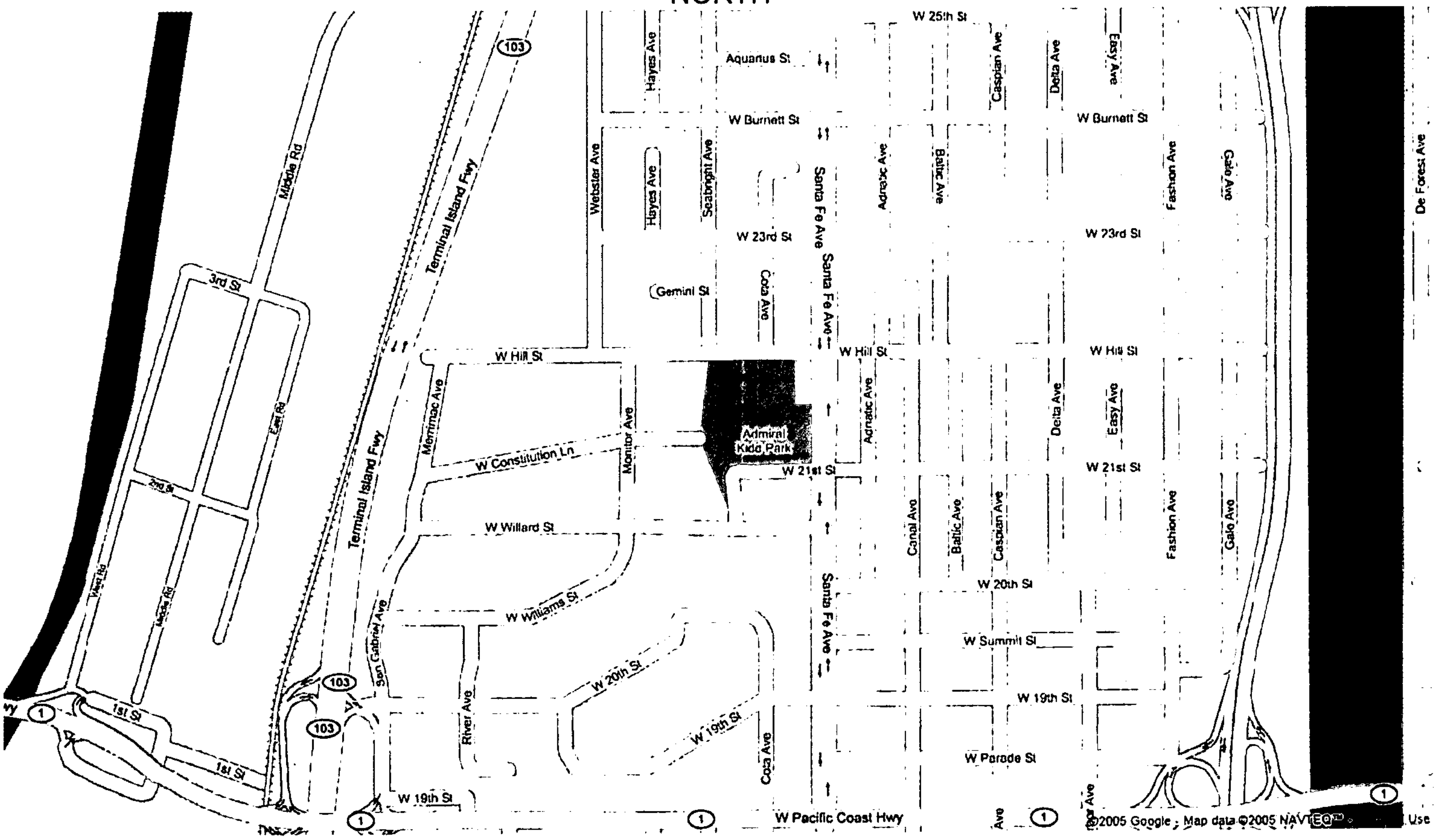
13. Usted cree que los negocios de ventas e industrias del cargo (barcos, trenes, camiones) quien contaminan y causan problemas de salud para el publico tienen que pagar para la ayuda de seguro de salud? ____ Si ____ No
14. Usted cree que California tiene que invertir en mejores modos del transportación que no causan tanta contaminación. ____ Si _____ No

APPENDIX B



710
Neighborhood
Port of Long
Beach
©2008 Google - Imagery

NORTH


W 25th St
Aquarius St
W Burnett St
W Burnett St
Hayes Ave
Hayes Ave
Webster Ave
Seabright Ave
Santa Fe Ave
Adriatic Ave
Baltic Ave
Caspian Ave
Delta Ave
Easy Ave
Fashion Ave
Gale Ave
De Forest Ave
W 23rd St
W 23rd St
Gemini St
Cota Ave
Middle Rd
Terminal Island Fwy
3rd St
W Hill St
W Hill St
W Hill St
Merrimac Ave
Monitor Ave
W Constitution Ln
Admiral Kidd Park
W 21st St
W 21st St
East Rd
2nd St
W Willard St
Canal Ave
Baltic Ave
Caspian Ave
Fashion Ave
Gale Ave
Delta Ave
Easy Ave
Adriatic Ave
W 20th St
W Williams St
San Gabriel Ave
W Summit St
W 20th St
W 19th St
River Ave
W 19th St
1st St
1st St
Cota Ave
W Parade St
W 19th St
W Pacific Coast Hwy
103
1
©2005 Google - Map data ©2005 NAVTEQ™
Use

SOUTH

APPENDIX C

PROGRAM COSTS & COST EFFECTIVENESS MEASURES FOR CALIFORNIA PORT HDDV DPF RETROFIT AND HDDV REPLACEMENT STRATEGIES

C-1: INTRODUCTION

This Appendix discusses the costs associated with replacing and retrofitting on-road, Class 8 (GVWR > 33,000 lbs), heavy duty diesel vehicles (HDDVs) operating at California's Ports. The analysis begins with a discussion on the 2005 California Used HDDV market (Appendix C-2), and the price forecasting model developed to predict used HDDV replacement costs when older model year HDDVs are being replaced with newer model year vehicles.

The discussion of the used HDDV market is followed by a generalized discussion on the cost methodology used to determine total program costs, and cost effectiveness (Appendix C-3) for each of the California Port HDDV replacement strategies. The discussion on the cost methodology is followed by presentation of the program costs for each of the HDDV replacement program strategies considered (Program Strategies 1 and 2). From these estimates, average program costs per TEU container shipped, and cost effectiveness (CE) is then derived.

C-2: ANALYSIS OF THE 2005 CALIFORNIA USED HDDV MARKET

In this section of the Appendix, values of used HDDVs are forecasted using a trend line established from sample price data for HDDVs available for sale in California and the neighboring States of Arizona and Nevada. Projected prices are used to determine total HDDV replacement costs during the program years 2007 - 2010.

As the marketplace of HDDVs consists of several types of HDDVs, which include but are not limited to beverage trucks, car carriers, crane trucks, concrete mixers, dump trucks, flatbed trucks, fire trucks, van trucks, and refuse haulers to name a few, only specific class 8 HDDVs are capable of hauling containers at ports. These were considered for developing program costs. Other HDDVs which are not typically engaged in the transport of containers were excluded from this analysis.

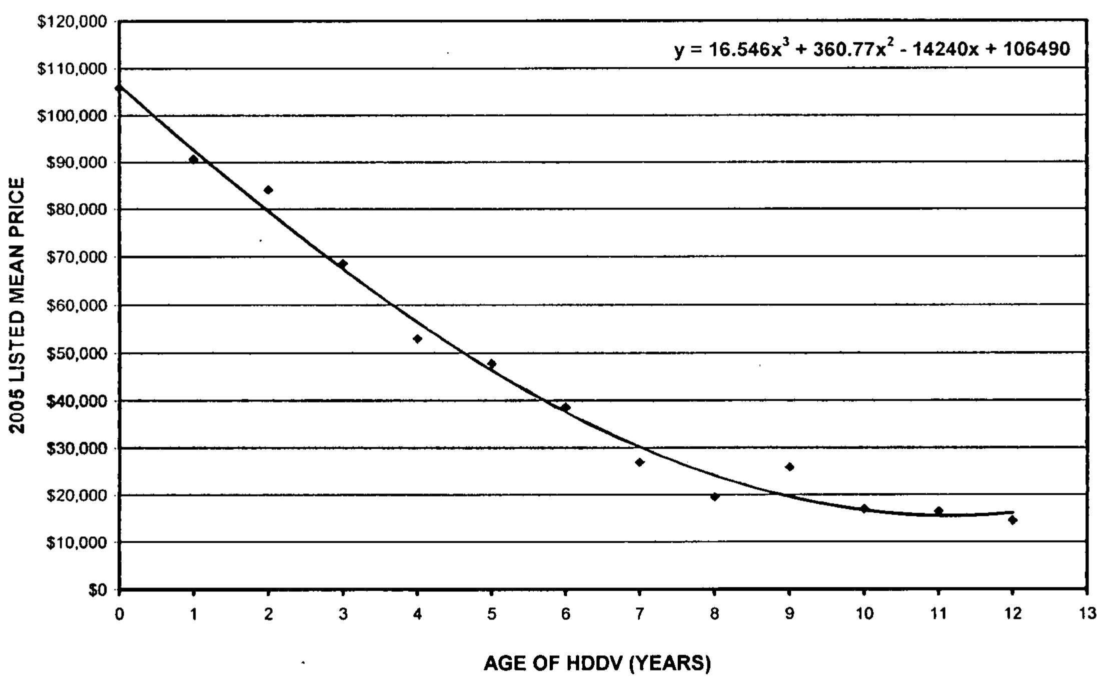
In selecting sample criteria to develop the vehicle age-price distribution profile, data from an internet site (TruckPaper.com, 2005) where listings of HDDVs for sale in California and the neighboring States of Arizona, Nevada are consolidated were used. Class 8 HDDV with a GVWR > 33,000 pounds, with and without sleeper cabins listings were selected in the search criteria. Of the 130 used and new HDDV listings with pricing information obtained, 80 or 62% were confirmed to be HDDVs with sleeper cabins, and 50 or 38% were regarded as HDDVs without sleeper cabins. Since many of the on-road HDDV operators engaged in the transport of containers at California Ports operate short haul routes, it was determined that including HDDVs without sleeper cabins in the search criteria was appropriate. Listed prices for vehicles obtained were for tractors only, and typically did not include additional equipment. Trailers at California's ports are typically supplied by the terminal.

2005 Used HDDV Prices and Forecasts of Prices for Program Years

In order to determine what the program costs are during any given year, HDDV replacement costs per vehicle were projected for that year. An internet survey of mean selling prices for 1994 - 2006 model year HDDVs described in section C-2 to develop a vehicle age-price distribution profile for the year 2005 was conducted. Also, it was further assumed that the value of a used HDDV established in 2005 will be an average value derived from survey results. The used HDDV value may differ depending on unforeseen fluctuations in market demand and prevailing economic conditions.

To determine the HDDV average value, price listings were grouped by model year and a mean price for each model year was developed. The mean price to develop the trend line for used HDDVs based on the age of the vehicle was used. Figure 2.1 below depicts this trend line developed from the survey.

FIGURE 2.1
2005 CALIFORNIA USED HDDV
PRICE-AGE DISTRIBUTION PROFILE FROM SURVEY



C-3: COST METHODOLOGY

This section of the Appendix discusses the cost methodology associated with the fleet modernization strategies. It is estimated that after full implementation, 20,000 – 40,000 California port HDDVs may be equipped with a form of level 3 DECS. The DPF retrofit costs are common to all port HDDV strategies and are discussed in detail in sections A-4, A-5, and A-6. The primary difference between the two strategies is the reduction in oxides of nitrogen (NOx) emissions achieved by replacing older model year HDDVs with newer model year HDDVs. After individual strategy costs were developed, total present value program costs, and total strategy costs per twenty foot equivalent (TEU) container for the combined HDDV retrofit and replacement strategies were compiled. From total program costs, cost effectiveness on the total annualized costs for the combined retrofit and replacement strategies were then determined. Present value was determined for the reference date of December 31, 2005.

The cost effectiveness measure permits a direct comparison of one strategy with another. Total annualized costs, and annual emissions reduced are used to determine the cost effectiveness of each strategy. The annualized strategy cost is the amortization (capital recovery) of the individual strategy costs based on the project life of the respective strategy, and a prevailing discount rate. The annualized strategy cost is represented by the following equation:

Annualized Strategy Costs = Individual Strategy Costs x Capital Recovery Factor

The capital recovery factor (CRF) can be derived from the following equation by assuming a discount rate, (i), per period, and the number of compounding periods, (n). The number of compounding periods (n) corresponds to the project life of the strategy:

$$\text{Capital Recovery Factor (CRF)} = \frac{(i) * (1 + i)^n}{(1 + i)^n - 1}$$

It is estimated that retrofit and replacement of California Port HDDV would each have a project life of 5 years, and prevailing discount rates would vary between 4 percent (Carl Moyer Program, 2005), and 7 percent (ARB Research Department, 2005). Assuming a 7 percent discount rate (i) scenario, and a 5 year project life (n), the capital recovery factor (CRF) is calculated using the above equation and found to be 0.2439. The annualized strategy cost is obtained from the product of the capital recovery factor and the individual strategy cost estimate for its project life.

Total annualized strategy costs for California Port HDDV are then determined by combining annualized HDDV DPF retrofit strategy costs with annualized HDDV replacement costs for each strategy. Having once obtained the total annualized strategy costs, the measure of cost effectiveness is then derived for the California Port HDDV retrofit and replacement strategy strategies. The cost effectiveness calculation is represented by the following equation:

$$\text{Cost Effectiveness (CE) (\$ /Ton)} = \frac{\text{Total Annualized Strategy Costs (\$/Year)}}{\text{Annual Weighted Emissions Reduction Factor (Tons/Year)}}$$

The measure of the annual weighted emissions reduction is a weighted factor that takes into consideration annual reductions of oxides of nitrogen (NOx), reactive organic gases (ROG), and combustible particulate matter (PM) emissions. When compared to emissions of NOx and ROG, PM emissions are considered by ARB to be more harmful to human health, and are therefore weighted more heavily in the annual weighted emissions reduction factor. In the equation for the annual emissions reduction factor represented below, PM emissions reduced is weighted by a factor of 20 (Carl Moyer Program, 2005), and annual emissions reduction are determined by summing NOx, ROG, and PM emissions reduced:

$$\text{Annual Weighted Emissions Reduction Factor} = \text{(NOx + ROG + 20*PM) Reduced (Tons/Year)}$$

The cost effectiveness is then obtained from the ratio of the total annualized strategy costs to the annual weighted emissions reduction factor as depicted in the following resulting equation:

$$\text{Cost Effectiveness (CE) (\$/Ton)} = \frac{\text{Total Annualized Strategy Costs (\$/Year)}}{\text{(NOx + ROG + 20*PM) (Reduced)(Tons/Year)}}$$

C-4: COST OF CALIFORNIA PORT STRATEGY 1

In this strategy, all pre-1994 model year California Port HDDVs are replaced with 1994 - 1998 model year HDDVs over four years beginning in the year 2007. A phased-in HDDV replacement scenario whereby 25 percent of the qualified pre-1994 California Port HDDV fleet is replaced every year until 2010 was assumed. It is estimated that in the year 2007, about 72 percent of the current California Port HDDV fleet, or 14,400 vehicles (3,600 vehicles per year over 4 years) may qualify for this replacement strategy. This strategy for replacing older HDDV in California Port service is expected to reduce NOx emissions by an estimated 963 tons in 2010, from established baseline (pre-replacement) levels. In addition, the entire fleet of qualified HDDVs will be required to install a DPF. Diesel PM emissions from 20,000 HDDVs (5,000 vehicles per year) are expected to be reduced by an estimated 100 tons in 2010, from established baseline (pre-retrofit) levels.

California Port HDDV DPF Retrofit Strategy Costs

The costs for retrofitting 20,000 HDDVs during a phased-in period scenario beginning 2007 and ending 2010 are examined. An estimated 5,000 HDDVs per year will be retrofitted with a 3 DPF, and PM emissions will be reduced by 100 tons per year after the strategy is fully implemented in 2010.

The HDDV DPF retrofit strategy cost is based on a passive DPF product and installation cost of $8,500 provided by vendor (Ironman Parts and Service, 2005). This cost estimate is exclusive of state and local taxes. Additionally, in the year 2007 (projected retrofit strategy start date), the DPF manufacturing industry may capture economies of scale, and the price of a DPF may decrease. It is also assumed that there will be a contract charge of $1,110 associated with an annual cost of $200 (Ironman Parts & Service, 2005) to service the DPF product over its project life of five (5) years. This DPF service requirement is recommended every 50,000 miles or once a year (Fleetgaurd Emissions Solutions / Ironman Parts & Service, 2005).

The total cost to retrofit 20,000 HDDV is estimated to be in the range of $163 million - $174 million, corresponding to discount rates of 7 percent and 4 percent, respectively, as presented in Table 4.1 below. For 40,000 qualifying vehicles, total retrofit costs are estimated to be $326 million - $349 million.

TABLE 4.1
CALIFORNIA PORT HDDV DPF RETROFIT COSTS & ANNUAL DIESEL PM EMISSIONS REDUCTION

YEAR OF STRATEGY	TOTAL DPF, INSTALLATION, & 5-YEAR O&M COSTS	FLEET QUALIFIED FOR DPF RETROFIT	TOTAL DPF COSTS (DPF COSTS X QUALIFIED FLEET)	12/31/2005 PRESENT VALUE OF DPF COSTS DISCOUNTED AT 4% & 7%	ANNUAL DIESEL PM EMISSIONS REDUCTION (TONS/YEAR)
1/1/2007	$ 9,610	5,000	$ 48,052,472	$ 44,908,853 To $ 46,204,300	25
1/1/2008	$ 9,610	5,000	$ 48,052,472	$ 41,970,890 To $ 44,427,212	25
1/1/2009	$ 9,610	5,000	$ 48,052,472	$ 39,225,131 To $ 42,718,473	25
1/1/2010	$ 9,610	5,000	$ 48,052,472	$ 36,659,001 To $ 41,075,455	25
TOTAL	-	**20,000**	-	**$ 162,763,875 To $ 174,425,439**	**100**

California Port HDDV Costs for Replacement Strategy 1

Based on a 2005 data of used HDDV prices in California and neighboring States, it is further estimated that the cost of replacement of a pre-1994 model year HDDV is projected to be approximately $16,700 for a 10-year old HDDV in the year 2007, and $15,500 for a 11-year old HDDV in 2008. Thereafter, replacement costs for 12-year and 13-year old HDDVs in 2009 and 2010, respectively, are expected to remain at $15,500. This value is predicted by the HDDV pricing model (see trend line in Figure 2.1).

Total HDDV replacement costs are expected to be in the range of $193 million to $207 million (present value as determined on December 31, 2005), corresponding to discount rates of 7 percent and 4 percent, respectively, and are presented in Table 4.2. For 28,800 qualifying pre-1994 vehicles, total HDDV replacement costs for replacement strategy 1 are estimated to be $387 million - $414 million. Yearly costs are presented in Table 4.2.

TABLE 4.2
CALIFORNIA PORT COSTS FOR HDDV REPLACEMENT

HDDV REPLACEMENT SCHEDULE	ESTIMATED NUMBER OF QUALIFIED HDDV	REPLACEMENT COSTS / VEHICLE	TOTAL YEARLY COSTS	(12/31/2005) PRESENT VALUE
25% of Pre-1994 With 10-Year Old HDDV in 2007	3,600	$ 16,713	$ 60,166,800	$ 56,230,654 To $ 57,852,692
25% of Pre-1994 With 11-Year Old HDDV in 2008	3,600	$ 15,526	$ 55,893,226	$ 48,819,308 To $ 51,676,429
25% of Pre-1994 With 12-Year Old HDDV in 2009	3,600	$ 15,526	$ 55,893,226	$ 45,625,521 To $ 49,688,874
25% of Pre-1994 With 13-Year Old HDDV in 2010	3,600	$ 15,526	$ 55,893,226	$ 42,640,674 To $ 47,777,763
TOTAL	**14,400**			**$ 193,316,158 To $ 206,996,759**

California Port HDDV Total Costs (Retrofit & Replacement) for Strategy 1

Total costs for Strategy 1 are found to be in the range $356 million to $381 million, corresponding to discount rates of 7 percent and 4 percent, respectively. Total costs were determined as a present value on December 31, 2005. For 40,000 qualifying vehicles, total HDDV DPF retrofit and HDDV replacement costs (Strategy 1) are estimated to be $712 million - $763 million. Yearly costs are presented in Table 4.3.

TABLE 4.3
TOTAL COMBINED COSTS FOR HDDV REPLACEMENT & DPF RETROFIT STRATEGY 1

HDDV REPLACEMENT & DPF RETROFIT SCHEDULE	**DPF RETROFIT COSTS (12/31/2005)**	**HDDV REPLACEMENT COSTS (12/31/2005)**	**(12/31/2005) TOTAL YEARLY COSTS**
Pre-1994 With 10 Year Old HDDV in 2007 + 25% DPF in 2007	$ 44,908,853 To $ 46,204,300	$ 56,230,654 To $ 57,852,692	$ 101,139,507 To $ 104,056,993
Pre-1994 With 11 Year Old HDDV in 2008 + 25% DPF in 2008	$ 41,970,890 To $ 44,427,212	$ 48,819,308 To $ 51,676,429	$ 90,790,198 To $ 96,103,641
Pre-1994 With 12 Year Old HDDV in 2009 + 25% DPF in 2009	$ 39,225,131 To $ 42,718,473	$ 45,625,521 To $ 49,688,874	$ 84,850,652 To $ 92,407,347
Pre-1994 With 13 Year Old HDDV in 2010 + 25% DPF in 2010	$ 36,659,001 To $ 41,075,455	$ 42,640,674 To $ 47,777,763	$ 79,299,675 To $ 88,853,218
TOTAL COSTS	**$ 162,763,875 To $ 174,425,439**	**$ 193,316,158 To $ 206,995,759**	**$ 356,080,032 To $ 381,421,198**

California Port HDDV Total Costs Per TEU Container for Strategy 1

TEU container shipping volumes for the four major California Ports (Ports of Los Angeles, Long Beach, Oakland, and San Diego) were compiled for the year 2005 (ARB Staff Research, 2005). TEU container shipping volumes were then projected for the years (2007 – 2010) during which the HDDVs are to be replaced using the average of the Federal Highway Administration (FWHA) predicted growth rate in container volume (Federal Highway Administration, 2005), and the historic (1990 – 2000) growth rate of the California Port container volume (ARB, 2005). This rate was found to be approximately 6%. It was estimated that 20 million – 24 million containers per year combined (on-road and rail) will be shipped between the 2007 – 2010 period.

Average projected costs for the California Port HDDV Strategy 1 (20,000 qualifying vehicles) were found to be $4.1 - $4.4 per TEU container shipped per year for four years. Yearly strategy costs per TEU Container are summarized in Table 4.4.

TABLE 4.4
TOTAL STRATEGY COSTS PER TEU CONTAINER FOR STRATEGY 1

HDDV REPLACEMENT & DPF RETROFIT SCHEDULE	TOTAL STRATEGY COSTS (DISCOUNT RATE OF 4%)	TOTAL STRATEGY COSTS (DISCOUNT RATE OF 7%)	PROJECTED ANNUAL TEU CONTAINER SHIPMENTS	PROJECTED STRATEGY COSTS PER TEU CONTAINER (DISCOUNT RATE OF 4%)	PROJECTED STRATEGY COSTS PER TEU CONTAINER (DISCOUNT RATE OF 7%)
Pre-1994 With 10 Year Old HDDV in 2007 + 25% DPF in 2007	$ 104,056,993	$ 101,139,507	20,083,989	$ 5.2	$ 5.0
Pre-1994 With 11 Year Old HDDV in 2008 + 25% DPF in 2008	$ 96,103,641	$ 90,790,198	21,273,965	$ 4.5	$ 4.3
Pre-1994 With 12 Year Old HDDV in 2009 + 25% DPF in 2009	$ 92,407,347	$ 84,850,652	22,534,448	$ 4.1	$ 3.8
Pre-1994 With 13 Year Old HDDV in 2010 + 25% DPF in 2010	$ 88,853,218	$ 79,299,675	23,869,614	$ 3.7	$ 3.3
TOTAL	**$381,421,198**	**$ 356,080,032**	**87,762,016**	**$ 4.38 (AVERAGE)**	**$ 4.1 (AVERAGE)**

Cost Effectiveness Measure for California Port HDDV Strategy 1

As discussed in Appendix C-3 (Cost Methodology), the cost effectiveness is derived from the following equation:

$$\text{Cost Effectiveness (CE) (\$/Ton)} = \frac{\text{Total Annualized Strategy Costs (\$/Year)}}{(NOx + ROG + 20*PM)\ \text{(Reduced)(Tons/Year)}}$$

The total annualized costs for a California Port HDDV Strategy are obtained from the individual HDDV DPF retrofit, and HDDV replacement costs, and the amortization of the individual strategy costs.

Annualized Costs for the California Port HDDV DPF Retrofit Strategy

For the California Port HDDV DPF retrofit strategy, it was assumed that the project life for DPF retrofits to be 5 years. For the phased-in scenario of the DPF retrofit strategy beginning in 2007 and ending in 2010, It was estimated that the annualized costs would range from $10.9 million per year (2007) to $8.9 million per year (2010), determined at a discount rate of 7 percent. Similarly, at a discount rate of 4 percent, It was estimated the annualized costs would range from $10.4 million per year (2007) to $9.3 million per year (2010). These costs are summarized in Table 4.5.

<u>Annualized Costs for the California Port HDDV Replacement Strategy 1</u>

The annualized HDDV replacement cost for the phased-in scenario of replacement strategy 1 (replacement of pre-1994 California Port HDDV with 1994 - 1998 model year HDDVs beginning in 2007, and ending in 2010), was found to range from $13.7 million per year (2007) to $10.4 million per year (2010), determined at a discount rate of 7 percent. At a discount rate of 4 percent, the annualized costs were found to range from $13.0 million per year (2007) to $10.7 million per year (2010). These costs are summarized in Table 4.5.

<u>Total Annualized Costs for California Port HDDV Strategy 1</u>

The annualized HDDV DPF retrofit strategy costs are combined with the annualized HDDV replacement strategy 1 costs discussed above to estimate the total annualized costs for Strategy 1. Total annualized costs are presented in Table 4.5. The range of values in the table reflects discounting costs to present value at 4 percent and 7 percent.

<u>Annual Weighted Emissions Reduction Factor for Strategy 1</u>

As discussed in the Cost Methodology (see Appendix C-2), the annual weighted emissions reduction is derived from the reductions in NOx and PM emissions as a result of the HDDV DPF retrofit and the HDDV replacement strategy. This factor was computed to be 741 tons (20 x 25 tons PM + 241 tons NOx) for each year of the strategy during which this strategy is implemented.

<u>Cost Effectiveness Measure for Strategy 1</u>

The cost-effectiveness of Strategy 1 is determined by computing the ratio of the total annualized strategy costs to the total annual weighted emissions reduction factor, and is presented in Table 4.5. The cost effectiveness was found to range from $26,000 - $33,000 per ton of pollutant reduced for Strategy 1.

TABLE 4.5
ANNUALIZED COSTS, ANNUAL EMISSIONS REDUCTION, & COST EFFECTIVENESS FOR STRATEGY 1

HDDV REPLACEMENT & DPF RETROFIT SCHEDULE	ANNUALIZED COST OF HDDV REPLACEMENT	ANNUALIZED COST OF DPF RETROFIT	TOTAL ANNUALIZED COSTS	ANNUAL WEIGHTED EMISSIONS REDUCTION NOx + 20*PM) (TONS / YEAR)	COST EFFECTIVENESS ($ /TON)
Pre-1994 With 10 Year Old HDDV in 2007 + 25% DPF in 2007	$ 12,995,283 To $ 13,714,133	$ 10,378,739 To $ 10,952,851	$ 23,374,022 To $ 24,666,985	741	$ 31,555 To $ 33,300
Pre-1994 With 11 Year Old HDDV in 2008 + 25% DPF in 2008	$ 11,607,927 To $ 11,906,575	$ 9,979,556 To $ 10,236,310	$ 21,587,483 To $ 22,142,884	741	$ 29,143 To $ 29,893
Pre-1994 With 12 Year Old HDDV in 2009 + 25% DPF in 2009	$ 11,161,468 To $ 11,127,640	$ 9,595,727 To $ 9,566,644	$ 20,757,196 To $ 20,694,285	741	$ 28,022 To $ 27,937
Pre-1994 With 13 Year Old HDDV in 2010 + 25% DPF in 2010	$ 10,732,181 To $ 10,399,664	$ 9,226,661 To $ 8,940,789	$ 19,958,842 To $ 19,340,453	741	$ 26.944 To $ 26,109

C-5: COST OF CALIFORNIA PORT STRATEGY 2

In the other replacement strategy, all pre-2003 model year California Port HDDVs are replaced with 2003 or newer model year HDDVs over four years beginning in the year 2007. This strategy also provides a phased-in HDDV replacement scenario whereby 25 percent of the qualified pre-2003 California Port HDDV fleet is replaced every year until 2010. It is estimated that in the year 2007, almost all California Port HDDV vehicles, or 20,000 vehicles (5,000 vehicles per year) may qualify for this replacement strategy. This strategy for replacing older HDDV in California Port service is expected to reduce NOx emissions by an estimated 966 tons in 2007, 1,932 tons in 2008, 2,898 tons in 2009, and 3,864 tons in 2010, from established baseline (pre-replacement) levels. In addition, the entire fleet of qualified HDDVs will be required to install a DPF. It was expected that diesel PM emissions from 20,000 HDDVs (5,000 vehicles per year) to be reduced by an estimated 25 tons in 2007, 50 tons in 2008, 75 tons in 2009, and 100 tons in 2010, from established baseline (pre-retrofit) levels.

California Port HDDV DPF Retrofit Strategy Costs

The costs for retrofitting 20,000 HDDVs during a phased-in period scenario beginning 2007 and ending 2010 follows. An estimated 5,000 HDDVs per year will be retrofitted with a level 3 DPF, and PM emissions will be reduced by 100 tons per year after the strategy is fully implemented in 2010.

The HDDV DPF retrofit strategy cost is based on a passive DPF product and installation cost of $8,500 provided by vendor (Ironman Parts and Service, 2005). This cost estimate is exclusive of state and local taxes. Additionally, in the year 2007 (projected retrofit strategy start date), the DPF manufacturing industry may capture economies of scale, and the price of a DPF may decrease. It was also assumed that there wouldl be a contract charge of $1,110 associated with an annual cost of $200 (Ironman Parts & Service, 2005) to service the DPF product over its project life of five (5) years. This DPF service requirement is recommended every 50,000 miles or once a year (Fleetgaurd Emissions Solutions / Ironman Parts & Service, 2005).

The total cost to retrofit 20,000 HDDV is estimated to be in the range of $163 million - $174 million, corresponding to discount rates of 7 percent and 4 percent, respectively, as presented in Table 5.1 below. For 40,000 qualifying vehicles, total retrofit costs are estimated to be $326 million - $349 million.

TABLE 5.1
CALIFORNIA PORT HDDV DPF RETROFIT COSTS & ANNUAL DIESEL PM EMISSIONS REDUCTION

YEAR OF STRATEGY	TOTAL DPF, INSTALLATION, & 5-YEAR O&M COSTS	FLEET QUALIFIED FOR DPF RETROFIT	TOTAL DPF COSTS (DPF COSTS X QUALIFIED FLEET)	(12/31/2005) PRESENT VALUE OF DPF COSTS DISCOUNTED AT 4% & 7%	ANNUAL DIESEL PM EMISSIONS REDUCTION (TONS/YEAR)
1/1/2007	$ 9,610	5,000	$ 48,052,472	$ 44,908,853 To $ 46,204,300	25
1/1/2008	$ 9,610	5,000	$ 48,052,472	$ 41,970,890 To $ 44,427,212	25
1/1/2009	$ 9,610	5,000	$ 48,052,472	$ 39,225,131 To $ 42,718,473	25
1/1/2010	$ 9,610	5,000	$ 48,052,472	$ 36,659,001 To $ 41,075,455	25
TOTAL	**-**	**20,000**	**-**	**$ 162,763,875 To $ 174,425,439**	**100**

California Port HDDV Costs for Replacement Strategy 3

Based on 2005 data of used HDDV prices in California and neighboring States, it is further estimated that the cost of replacement of a pre-2003 model year HDDV is projected to be approximately $56,000 for a 4 year old HDDV in 2007, $46,000 for a 5-year old HDDV in 2008, $38,000 for a 6-year old HDDV in 2009, and $30,000 for a 7-year old HDDV in 2010. These values are predicted by the HDDV pricing model (see trend line in Figure C-2.1). The demand for 2003 model year HDDV could be strong and some HDDV operators and owners may be forced to buy newer model year vehicles if shortages persist. If this is the case, then buyers are likely to pay $7,500 to $15,000 more per vehicle per newer model year to replace their aged vehicles.

The replacement costs for this strategy are expected to be in the range $734 million to $781 million (present value as determined on December 31, 2005), and are presented in Table 6.2 below. For 40,000 qualifying pre-2003 vehicles, total HDDV replacement costs for replacement strategy 2 are estimated to be $1,469 million - $1,563 million. The range of replacement costs corresponds to discount rates of 7 percent and 4 percent, respectively.

TABLE 5.2
CALIFORNIA PORT COSTS FOR HDDV REPLACEMENT

HDDV REPLACEMENT SCHEDULE	ESTIMATED NUMBER OF QUALIFIED HDDV	REPLACEMENT COSTS / VEHICLE	TOTAL YEARLY COSTS 3	(12/31/2005) PRESENT VALUE
Pre-2003 With 4-Year Old HDDV in 2007	5,000	$ 56,361	$ 281,806,320	$ 263,370,393 To $ 270,967,615
Pre-2003 With 5-Year Old HDDV in 2008	5,000	$ 46,378	$ 231,887,500	$ 202,539,523 To $ 214,393,029
Pre-2003 With 6-Year Old HDDV in 2009	5,000	$ 37,612	$ 188,058,280	$ 153,511,575 To $ 167,183,126
Pre-2003 With 7-Year Old HDDV in 2010	5,000	$ 30,163	$ 150,815,040	$ 115,056,072 To $ 128,917,328
TOTAL	**20,000**	**-**	**-**	**$ 734,477,562 To $ 781,461,099**

California Port Total Costs (Retrofit & Replacement) for Strategy 2

Total costs for Strategy 2 are presented in Table 6.3, and are found to be in the range $897 million to $966 million, corresponding to discount rates of 7 percent and 4 percent, respectively. For 40,000 qualifying vehicles, total HDDV DPF retrofit and HDDV replacement costs (Strategy 2) are estimated to be $1,794 million - $1,912 million. Total costs were determined as a present value on December 31, 2005.

TABLE 5.3
TOTAL COMBINED COSTS FOR HDDV REPLACEMENT & DPF RETROFIT STRATEGY 2

HDDV REPLACEMENT & DPF RETROFIT SCHEDULE	DPF RETROFIT COSTS (12/31/2005)	HDDV REPLACEMENT COSTS (12/31/2005)	TOTAL YEARLY COSTS (12/31/2005)
Pre-2003 With 4 Year Old HDDV + 25% DPF in 2007	$ 44,908,853 To $ 46,204,300	$ 263,370,393 To $ 270,967,615	$ 308,279,245 To $ 317,171,916
Pre-2003 With 5 Year Old HDDV + 25% DPF in 2008	$ 41,970,890 To $ 44,427,212	$ 202,539,523 To $ 214,393,029	$ 244,510,413 To $ 258,820,241
Pre-2003 With 6 Year Old HDDV + 25% DPF in 2009	$ 39,225,131 To $ 42,718,473	$ 153,511,575 To $ 167,183,126	$ 192,736,706 To $ 209,901,599
Pre-2003 With 7 Year Old HDDV + 25% DPF in 2010	$ 36,659,001 To $ 41,075,455	$ 115,056,072 To $ 128,917,328	$ 151,715,073 To $ 169,992,783
TOTAL COSTS	**$ 162,763,875 To $ 174,425,439**	**$ 734,477,562 To $ 781,461,099**	**$ 897,241,437 To $ 955,886,538**

California Port HDDV Total Costs Per TEU Container for Strategy 2

TEU container shipping volumes for the four major California Ports (Ports of Los Angeles, Long Beach, Oakland, and San Diego) were compiled for the year 2005 (ARB Staff Research, 2005). TEU container shipping volumes were then projected for the years (2007 – 2010) during which the HDDVs are to be replaced using the average of the Federal Highway Administration (FWHA) predicted growth rate in container volume (Federal Highway Administration, 2005), and the historic (1990 – 2000) growth rate of the California Port container volume (ARB, 2005). This rate was found to be approximately 6%. It was estimated that 20 million – 24 million containers per year combined (on-road and rail) will be shipped between the 2007 – 2010 period.

Average projected costs for the California Port HDDV Strategy 2 (20,000 qualifying vehicles) were found to be $10.5 - $11.1 per TEU container shipped per year for four years. Yearly strategy costs per TEU Container are summarized in Table 5.4.

TABLE 5.4
COSTS PER TEU CONTAINER FOR STRATEGY 3

HDDV REPLACEMENT & DPF RETROFIT SCHEDULE	TOTAL STRATEGY COSTS (DISCOUNT RATE OF 4%)	TOTAL STRATEGY COSTS (DISCOUNT RATE OF 7%)	PROJECTED ANNUAL TEU CONTAINER SHIPMENTS	PROJECTED STRATEGY COSTS PER TEU CONTAINER (DISCOUNT RATE OF 4%)	PROJECTED STRATEGY COSTS PER TEU CONTAINER (DISCOUNT RATE OF 7%)
Pre-2003 With 4 Year Old HDDV + 25% DPF in 2007	$ 317,171,916	$ 308,279,245	20,083,989	$ 15.8	$ 15.3
Pre-2003 With 5 Year Old HDDV + 25% DPF in 2008	$ 258,820,241	$ 244,510,413	21,273,965	$ 12.2	$ 11.5
Pre-2003 With 6 Year Old HDDV + 25% DPF in 2009	$ 209,901,599	$ 192,736,706	22,534,448	$ 9.3	$ 8.6
Pre-2003 With 7 Year Old HDDV + 25% DPF in 2010	$ 169,992,783	$ 151,715,073	23,869,614	$ 7.1	$ 6.4
TOTAL	**$ 955,886,538**	**$ 897,241,437**	**87,762,016**	**$11.10 (AVERAGE)**	**$ 10.45 (AVERAGE)**

<u>Cost Effectiveness Measure for California Port HDDV Strategy 2</u>

As discussed in Appendix C-3 (Cost Methodology), the cost effectiveness is derived from the following equation:

$$\text{Cost Effectiveness (CE) (\$/Ton)} = \frac{\text{Total Annualized Strategy Costs (\$/Year)}}{\text{(NOx + ROG + 20*PM) (Reduced)(Tons/Year)}}$$

The total annualized costs for a California Port HDDV Strategy are obtained from the individual HDDV DPF retrofit, and HDDV replacement costs, and the amortization of the individual strategy costs.

<u>Annualized Costs for the California Port HDDV DPF Retrofit Strategy</u>

For the California Port HDDV DPF retrofit strategy, it was assumed the project life for DPF retrofits to be 5 years. For the optional phased-in scenario of the DPF retrofit strategy beginning in 2007 and ending in 2010, it was estimated that the annualized costs would range from $10.9 million per year (2007) to $8.9 million per year (2010), determined at a discount rate of 7 percent. Similarly, at a discount rate of 4 percent, it was estimated that the annualized costs would range from $10.4 million per year (2007) to $9.3 million per year (2010).

Annualized Costs for the California Port HDDV Replacement Strategy 3

The annualized HDDV replacement cost for the phased-in scenario of replacement strategy 2 (replacement of pre-2003 California Port HDDV with 2003 or later model year HDDV beginning in 2007, and ending in 2010), was found to range from $64.2 million per year (2007) to $28.1 million per year (2010), determined at a discount rate of 7 percent. At a discount rate of 4 percent, the annualized costs were found to range from $60.9 million per year (2007) to $30.0 million per year (2010).

Total Annualized Costs for the California Port HDDV Strategy 2

The annualized HDDV DPF retrofit strategy costs are combined with the annualized HDDV replacement strategy 2 costs discussed above to estimate the total annualized costs for Strategy 2. Total annualized costs are presented in Table 5.5 below. The range of values in the table reflects discounting costs to present value at 4 percent and 7 percent.

Annual Weighted Emissions Reduction Factor for Strategy 2

As discussed in the Cost Methodology (see Appendix C-2), the annual weighted emissions reduction is derived from the reductions in NOx and PM emissions as a result of the HDDV DPF retrofit and the HDDV replacement strategy. This factor was computed to be 1,466 tons (20 x 25 tons PM + 966 tons NOx) for each year of the strategy during which this strategy is implemented.

Cost Effectiveness Measure for Strategy 2

The cost-effectiveness of Strategy 2 is determined by computing the ratio of the total annualized strategy costs to the total annual weighted emissions reduction factor, and is presented in Table 5.5. The cost effectiveness was found to range from $25,000 - $51,000 per ton of pollutant reduced for Strategy 2.

TABLE 5.5
ANNUALIZED COSTS, ANNUAL EMISSIONS REDUCTIONS, & COST EFFECTIVENESS FOR STRATEGY 3

HDDV REPLACEMENT & DPF RETROFIT SCHEDULE	ANNUALIZED COST OF HDDV REPLACEMENT	ANNUALIZED COST OF DPF RETROFIT	TOTAL ANNUALIZEDCOSTS	ANNUAL WEIGHTED EMISSIONS REDUCTIONS (NOx + 20*PM)	COST EFFECTIVENESS ($ /TON)
Pre-2003 With 4 Year Old HDDV + 25% DPF in 2007	$ 60,866,673 To $ 64,233,588	$ 10,378,739 To $ 10,952,851	$ 71,245,412 To $ 75,186,439	1,466	$ 48,615 To $ 51,304
Pre-2003 With 5 Year Old HDDV + 25% DPF in 2008	$ 48,158,487 To $ 49,397,505	$ 9,979,556 To $ 10,236,310	$ 58,138,044 To $ 59,633,815	1,466	$ 39,671 To $ 40,692
Pre-2003 With 6 Year Old HDDV + 25% DPF in 2009	$ 37,553,863 To $ 37,440,045	$ 9,595,727 To $ 9,566,644	$ 47,149,590 To $ 47,006,689	1,466	$ 32,173 To $ 32,076
Pre-2003 With 7 Year Old HDDV + 25% DPF in 2010	$ 28,958,327 To $ 28,061,105	$ 9,226,661 To $ 8,940,789	$ 38,184,988 To $ 37,001,894	1,466	$ 26,056 To $ 25,249

APPENDIX D

EMISSION REDUCTION CALCULTION METHODOLOGY

Expected Emission Reduction for Port Trucks

Introduction

In this appendix, emission reductions associated with implementing of three emission reduction strategies presented in this paper will be discussed. All emission reductions are based on changes in port trucks population distribution corresponding to each proposed strategy. It is assumed that emissions and emission reductions are underestimated since they do not account for increases in emissions due to an increase in container volume between year 2002 (baseline inventory) and 2005 as well as contributions form small ports such as Sacramento or Stockton.

Trucks replacement strategies are presented below:

> **<u>Strategy #1: Replacement of 1993 MY and older trucks with reflashed 1994 to 1998 MY trucks and Installation of DPF on all trucks</u>**. It was estimated that under this strategy approximately 72 percent of the port fleet would have to be replaced.
>
> **<u>Strategy #2: Replacement of 2002 MY and older trucks with 2003 MY or newer trucks (NOx Engine Standard 2.5g/bhp-h) and installation of DPF on all trucks</u>**. Under this strategy 100 percent of the fleet would have to be replaced.

The primary difference between the strategies is the amount of NOx emissions reduction associated with replacing older models of HDDV with never trucks servicing ports.

PM Emission Reduction Calculation Methodology

To maximize PM emission reductions, it is assumed that replacement of all trucks that can't be retrofitted with DPFs (level 3 PM emission control technologies) will occur. Since model year 1994 and later trucks meet 0.1g/bhp-hr PM emission standards and can be equipped with a DPF, all pre-1994 trucks would have to be replaced. Assuming a DPF efficiency of 85 percent, it can be expect that the retrofitted port fleet to experience PM emission reductions of approximately 85 percent. Since both strategies recommend replacement of all pre-1994 trucks and installation of DPFs, PM emission reduction for both strategies would be equal. (see Table D-1). Additionally, because DPF regeneration is temperature and duty cycle dependant, ARB recommended that the temperature profile and duty cycle for port trucks should be developed before a wide spread DPF installations.

Table D-1: Estimated Projected Port Trucks PM Emission Benefits all Strategies After Full Implementation

Port truck PM emissions - Baseline (2002)	118 Tons/Year
Estimated PM Emissions with DPF (85 percent Reduction from Baseline)	18 Tons/Year
Emission Reductions	**100 Tons/Year**

NOx Emission Reductions Calculation Methodology

Substantial (greater then 25 percent) NOx reductions can be achieved only through a fleet modernization strategy because there are currently no existing verified technologies to reduce NOx emissions greater than 25 percent from existing trucks. Existing verified NOx reduction retrofitting technologies can provide only 25 percent reductions in NOx emissions and is not applicable for all 1993-2003 model year engines. Replacing the old trucks with NOx engine standards of 6g/bh/h and 4 g/bhp/h with trucks with engine standard of 2.5 g/bhp/h would provide the best NOx benefits (strategy 2 and 3). See Table D-2:

Table D-2: NOx Engine Standard by Heavy-Duty Diesel Vehicle Model Year and Corresponding Estimated Port Truck Population

Model year	Engine NOx emissions Standard in g/bhp/h	Percent of fleet
2003-2006	2.50	0
1991-2002	4.00	51
1988-1990	6.00	22
1970-1987	N/A*	27

* No federal NOx engine standards

To estimate NOx emission reductions for each strategy, EMFAC2002 along with the port truck population distribution corresponding to each proposed strategy and generated emission factors for each strategy were used. Generated emission factors will depend on the individual strategy because each strategy will result in a different port truck age distribution. It was then calculated the average emission factor decrease between the base line emission factors used in the Starcrest Study and the generated emission factors for each strategy.

Average Emission Factor Decrease (Percent Reduction)
= (1- (Strategy Emission Factor / Base Emission Factor)) X 100

Assuming constant miles traveled, the percentage decrease in emission factors is proportional to the decrease in NOx emissions. The baseline emission factors, strategy emission factors, and the resultant percent NOx emission reduction for each of the three strategies are detailed in Tables D-3 and D-4.

Table D-3: Emission Factors and NOx Reduction for Strategy #1

MPH	Base Emission Factor NOx g/m	Strategy #1 Emission Factors NOx g/m	Percent reduction
5	29.752	24.864	16%
10	24.684	20.629	16%
15	21.219	17.733	16%
20	18.900	15.795	16%
25	17.442	14.577	16%
30	16.679	13.939	16%
35	16.525	13.811	16%
40	16.965	14.178	16%
45	18.045	15.081	16%
50	19.888	16.622	16%
55	22.712	18.981	16%
60	26.873	22.459	16%
65	32.947	27.534	16%

Table D-4: Emission Factors and NOx Reduction for Strategy #2

MPH	Base Emission Factors NOx g/m	Strategy #3 Emission Factors NOx g/m	Percent reduction
5	29.752	10.711	64%
10	24.684	8.886	64%
15	21.219	7.639	64%
20	18.900	6.804	64%
25	17.442	6.279	64%
30	16.679	6.004	64%
35	16.525	5.949	64%
40	16.965	6.107	64%
45	18.045	6.496	64%
50	19.888	7.160	64%
55	22.712	8.176	64%
60	26.873	9.674	64%
65	32.947	11.861	64%

The percent NOx emission reductions for each of the strategies (detailed in Tables D-3 and D-4) were then used with the baseline emissions for port trucks generated by Starcrest to determine the NOx emission reductions (baseline emission methodology detailed in section II of this report). The following formula calculates NOx emission reductions.

NOx Emission Reductions = (NOx Base) - (NOx Base)(Percent Reduction)

Table D-5 provides a summary of potential NOx emission reductions for each of the three strategies.

Table D-5: Estimated Projected Port Trucks NOx Emission Benefits After Full Implementation

	NOx Base Tons/Year	Percent Reduction	Estimate NOx Tons/Year	Emission Reductions T/Y
Strategy # 1	6016	16%	5053	963
Strategy # 2	6016	64%	2154	3862

APPENDIX E

Emission Control Technologies/Strategies

Introduction

In this section, the staff of the ARB conducted the thorough review of the diesel PM and NOx reduction technologies currently available and projected to be available in the near future for diesel-fueled on road engines. These technologies and strategies may aid in reducing emissions from port trucks and may be integral to any port truck modernization strategy. For each technology, the ARB staff provided descriptions, discussions of potential limitations, described any in-use experiences, and identified solutions that have been verified by the ARB.

<u>Verification of Diesel Emission Control Strategies</u>

As a way to thoroughly evaluate the emissions reduction capabilities and durability of a variety of Diesel Emission Control Strategy (DECS), ARB has developed the Diesel Emission Control Strategy Verification Procedure (Procedure) (ARB, 2003). The purpose of the Procedure is to verify strategies that provide reductions in diesel PM and NOx emissions. There are currently three levels of emission reduction technologies: level 1 achieves a minimum emission reduction of 25 percent, level 2 achieves a minimum of 50 percent and level 3 achieves a minimum of 85 percent. All ARB verified DECS are verified for one of these levels.

A complete and up-to-date list of verified DECS and the engine families, for which they have been verified, along with letters of verification, warranty, and coverage information may be found on our web site at: http://www.arb.ca.gov/diesel/verdev/verdev.htm

A variety of strategies can be used for controlling emissions from diesel engines, including after treatment hardware, fuel strategies, and engine modifications. The two main types of technologies discussed here are add-on technologies such as DPFs and DOC, and fuel types or fuel additives. These technologies can also be combined to form additional DECS. Additional, this report will discuss repowering to a cleaner engine.

<u>Hardware Diesel Emission Control Strategies</u>

Diesel Particulate Filter

A DPF consists of a porous substrate that permits gases in the exhaust to pass through but traps the PM. DPFs are very efficient in reducing diesel PM emissions and achieve typical diesel PM reductions in excess of 90 percent. Most DPFs employ some means to periodically regenerate the filter (burn off the accumulated PM). A particulate filter can either be regenerated passively or actively.

Passive Diesel Particulate Filter (MECA, 2004)

A passive catalyzed DPF reduces diesel PM, carbon monoxide (CO) and hydrocarbon (HC) emissions through catalytic oxidation and filtration. Most of the DPFs sold in the United States use substrates consisting of ceramic wall-flow monoliths to capture the diesel particulates. Some manufacturers offer silicon carbide or other metallic substrates, but these are less commonly used in the United States.

These wall-flow monoliths are either coated with a catalyst material, typically a platinum group metal, or a separate catalyst is installed upstream of the particulate filter. The filter is positioned in the exhaust stream to trap or collect a significant fraction of the particulate emissions while allowing the exhaust gases to pass through the system.

Effective operation of a DPF requires a balance between PM collection and PM oxidation, or regeneration. Regeneration is accomplished by either raising the exhaust gas temperature or by lowering the diesel PM ignition temperature through the use of a catalyst. The type of filter technology that uses a catalyst to lower the diesel PM ignition temperature is termed a passive DPF, because no outside source of energy is required for regeneration.

Passive DPFs have demonstrated reductions in excess of 90 percent for diesel PM, along with similar reductions in CO and HC. A passive DPF is a very attractive means of reducing diesel PM emissions because of the combination of high reductions in PM emissions and minimal operation and maintenance requirements.

The successful application of a passive DPF is primarily determined by the average exhaust temperature at the filter's inlet and the rate of diesel PM generated by the engine. These two quantities are determined by a host of factors pertaining to both the details of the application and the state and type of engine being employed. As a result, the technical information provided to ARB for verification by the manufacturer serves as a guide, but additional information may be required to determine whether a passive DPF will be successful in a given application.

The rate of PM generation is influenced by a variety of factors and the engine certification level cannot be used, in all cases, to predict diesel PM emission levels in-use. Testing done by West Virginia University, for example, shows that a given diesel truck can generate a wide range of diesel PM emission levels depending on the test cycle. Engine maintenance is another factor in determining the actual diesel PM emission rate. The ARB's informational package for the heavy-duty vehicle inspection programs lists sixteen different common causes of high smoke levels related to engine maintenance (ARB, 1999).

The average exhaust temperature in actual use is also difficult to predict based on commonly documented engine characteristics, such as the exhaust temperature at peak power and peak torque. The exhaust temperature at the DPF inlet is highly application dependent, in that the particular duty cycle of the truck plays a prominent role, as do heat losses in the exhaust system. Very vehicle-specific characteristics enter the heat loss equation, such as the length of piping exhaust must travel through before it reaches the DPF. Lower average exhaust temperatures can also be the result of operating vehicles with engines oversized for the application.

The Passive DPF for Heavy Duty Diesel Vehicles is expected to be priced at approximately $8,000 plus cost of custom installation. In addition, approximately $400 per year for DPF maintenance service may be expected (Ironman Parts, 2005).

Active Diesel Particulate Filter

An active DPF system uses an external source of heat to oxidize the accumulated PM trapped in the filter. The most common methods of generating additional heat for oxidation involve passing a current through the filter medium, injecting fuel, or adding a fuel-borne catalyst or other reagent. Some active DPFs induce regeneration automatically when a specified backpressure is reached. Others use an indicator, such as a warning light, to alert the operator that regeneration is needed, and require the operator to initiate the regeneration process. Still other active systems collect and store diesel PM during engine operation and are regenerated at the end of the shift when the vehicle or equipment is shut off. A number of the filters are removed and regenerated externally at a regeneration station.

For applications in which engine diesel PM emissions are relatively high, and the exhaust temperature is relatively cool, actively regenerated systems may be more effective than passive systems because active DPFs (ARB, 2003) are not dependent on the heat carried in the exhaust for regeneration.

ARB staff has determined that there are currently available active DPFs (Cummins, 2004) (regeneration process is activated at the end of the day or shift by plugging into a 220 V AC electrical outlet) with the cost of $14,000 including installation.

Flow Through Filter

Flow-through filter technology (FTF) is a relatively new method for reducing diesel PM emissions. Unlike a DPF, in which only gases can pass through the substrate, the FTF does not physically "trap" and accumulate diesel PM. Instead, exhaust flows through a medium (such as a wire mesh) that has a high density of torturous flow channels, thus giving rise to turbulent flow conditions. The medium is typically treated with an oxidizing catalyst that is able to reduce emissions of diesel PM, HC, and CO, or used in conjunction with a fuel-borne catalyst. Any particles that are not oxidized within the FTF, flow out with the rest of the exhaust and do not accumulate in the DECS.
Consequently, the filtration efficiency of an FTF is lower than that of a DPF, but the FTF is much less likely to plug under unfavorable conditions, such as high PM engine emissions and low exhaust temperatures. Therefore, the FTF is a candidate for use in some applications unsuitable for DPFs. It is expected that

an FTF will achieve between 30 and 60 percent PM reduction.

Relative to a DOC, which typically has straight flow passages and laminar flow conditions; the FTF achieves a greater diesel PM reduction because of enhanced contact of the PM with the catalytic surfaces and longer residence times. The better performance of an FTF when compared to a DOC may come at the cost of increased backpressure.

ARB staff has determined that FTF could cost $4,000 - $6,000 plus cost of installation. There is an additional cost associated with FTF that are designed to be used with fuel borne catalysts (FBC). Based on FBC dosing requirements, the additional cost associated with FBC use in FTF is estimated to be $90 - $105 per gallon or approximately a $0.05 - $0.07 premium per gallon of diesel fuel (Clean Diesel Technology, 2005). Typical FBC dosage requirements are one gallon of FBC per 1,500 gallons of diesel fuel consumed, and that fuel economy improvements from use of FBC are approximately twice the costs of the product.

Diesel Oxidation Catalyst

A Diesel Oxidation Catalyst (DOC) reduces emissions of CO, HC, and the soluble organic fraction of diesel PM through catalytic oxidation alone. Exhaust gases are not filtered, as in the DPF. In the presence of a catalyst material and oxygen, CO, HC, and the soluble organic fraction undergo a chemical reaction and are converted into carbon dioxide and water. Some manufacturers integrate HC traps (zeolites) and sulfate suppressants into their oxidation catalysts. HC traps enhance HC reduction efficiency at lower exhaust temperatures and sulfate suppressants minimize the generation of sulfates at higher exhaust temperatures. A DOC can reduce total PM emissions up to 30 percent (level 1 technology).

ARB staff has determined that DOC muffler costs in the range of $1,000 - $1,500 plus cost of installation. There are no annual service or maintenance requirements associated with the product.

<u>Fuels and Fuel Additives Diesel Emission Control Strategies</u>

Fuel Additives

A fuel additive as a DECS is designed to be added to fuel or fuel systems so it is present in-cylinder during combustion and its addition causes a reduction in exhaust emissions. Additives can reduce the total mass of PM, with variable effects on CO, NO_x and gaseous HC production. The range of PM reductions of fuel additives is from 15 to 50 percent reduction in mass. Most additives are fairly insensitive to fuel sulfur content and will work with a range of sulfur concentrations as well as different fuels and other fuel additives.

An additive added to diesel fuel in order to aid in soot removal in DPFs by decreasing the ignition temperature of the carbonaceous exhaust is often called FBC. These can be used in conjunction with both passive and active filter systems to improve fuel economy, aid system performance, and decrease mass PM emissions. FBC/DPF systems are widely used in Europe and typically achieve a minimum of 85 percent reduction in PM emissions. Additives based on cerium, platinum, iron, and strontium are currently available, or may become available for use in the future in California.

There is a recurrent cost associated with FBC usage, approximately 1 gallon of FBC is required per 1,500 gallons of diesel fuel consumed by the engine. ARB staff has determined that FBC costs could be in the range of $90 - $105 per gallon or approximately a $0.05 - $0.07 premium per gallon of diesel fuel (Clean Diesel Technology, 2005). Fuel economy savings from use of FBC should offset the cost of the product (approximately twice the costs of the product).

Technology Combinations

A trend in technologies is to combine more than one technology to maximize the amount of diesel PM reduction. This section discusses some of these combinations.

Diesel Particulate Filter with NOx Catalyst

The Clēaire Longview system for specific 1994 to 2003 year diesel engines combines a catalyzed DPF and a NOx reducing catalyst to achieve 85 percent PM reduction, and 25 percent NOx reduction, respectively. The system is verified to Level 3 for PM reduction and Level 1 for NOx reduction.

ARB staff has determined that the system for HDDV costs $19,000 - $21,000, including installation. The manufacture estimates that annual maintenance and service of the system could cost an additional $200 per year. Replacement costs are estimated to be $8,500 for the DPF, and $7,000 for the NOx reducing catalyst after the useful life of the product (10 Years).

Diesel Oxidation Catalyst plus Spiracle™

The Donaldson Company has verified two combination systems at Level 1. Each system uses a different DOC, but both systems install a closed loop crankcase with the Donaldson Spiracle ™ closed crankcase filtration system. The systems are verified for use in certain 1991 and later model year collection vehicles. One system is verified for use with California diesel fuel and the other is verified for use with low sulfur diesel fuel.

The DOC plus Spiracle™ manufactured by the Donaldson Company for HDDV is expected to be priced at $2,300 plus $750 for installation. In addition, staff has determined that there would be a cost of $200 - $500 per year to periodically replace product element and service the unit.

Fuel-Borne Catalyst with Hardware Technology

A FBC can be combined with any of the three hardware technologies discussed above, the DPF, DOC, or FTF. The combination of a FBC with a DPF functions similarly to a catalyzed DPF, but a FBC allows the DPF to be lightly catalyzed. The FBC enhances DPF regeneration by encouraging better contact between the PM and the catalyst material. The FBC plus DPF combination reduces both the carbonaceous and soluble organic fractions of diesel PM. The primary benefit of this combination is a reduction in the amount of NO_2 generated as a proportion of NO_x.

There is a recurrent cost associated with FBC usage, approximately one gallon of FBC is required per 1,500 gallons of diesel fuel consumed by the engine. The ARB staff has determined that FBC costs could be in the range of $90 - $105 per gallon or approximately a $0.05 - $0.07 premium per gallon of diesel fuel (Clean Diesel Technology, 2005). Fuel economy savings from use of FBC should offset the cost of the product (approximately twice the costs of the product).

Engines

New Diesel Engine Meeting 0.01 g/bhp-hr for PM as a Repower or as Original Equipment

The particulate emission standard of 0.01 g/bhp-hr for heavy-duty highway diesel engines will take effect nationally and in California beginning with model year 2007, except for urban bus engines to be sold in California. The same standard for urban bus engines is already in effect in California for engines produced after October 1, 2002. These standards are based on the use of high-efficiency catalytic exhaust emission control devices or comparably effective advanced technologies. Because the devices expected to be used to meet the standard are made less efficient by sulfur in the exhaust stream, the level of sulfur in highway diesel fuel will also be reduced by 90 percent, relative to California diesel fuel sulfur levels, by mid-2006 to less than 15 ppmw.

Engine Repower Limitations

Another option is to repower an older vehicle by installing a pre-2007 MY engine along with a DECS. For example, any 1994 to 2006 MY engine with an aftermarket verified DPF would achieve PM emissions near 0.01 g/bhp-hr.

Repowering to a 0.01 g/bhp-hr engine is not always possible. The engine compartment may not be large enough to install a newer, electronic controlled engine where previously a mechanical engine was housed. Otherwise, the cost of converting from mechanical to electronic fuel injection may outweigh the value of the vehicle or remaining vehicle life.

Heavy-Duty Pilot Ignition Engine

A heavy-duty pilot ignition engine is a compression-ignition engine that operates on natural gas but uses diesel as a pilot ignition source. The total use of diesel is around six percent of the fuel consumed. ARB has defined this engine in its fleet rule for transit agencies and in the proposed rule for solid waste collection vehicles as an engine that uses diesel fuel at a ratio of no more than one part diesel fuel to ten parts total fuel on an energy equivalent basis. Furthermore, the engine cannot idle or operate solely on diesel fuel at any time. An engine that meets this definition and is certified to the lower optional PM standard (0.01 g/bhp-hr) would be classified as an alternative-fuel engine.

Experience with Passive Diesel Particulate Filters (MECA 2005)

Passive DPFs have been successfully used in numerous applications and as of 2005, over 130,000 trucks and buses had been retrofitted worldwide (MECA 2005). In the United States, the use of DPFs is growing largely due to DPF retrofit programs underway in California, New York, and Texas. In California, diesel-fueled school buses, solid waist collection vehicles, urban transit buses, medium-duty delivery vehicles, and fuel tanker trucks have been retrofitted with DPFs through various demonstration programs.

ARCO, a BP company, completed a one-year demonstration program in 2001 to evaluate low sulfur (less than15 parts per million by weight sulfur content) diesel fuel and passive DPFs in five truck and bus fleets. The five fleets, all of which operated in southern California, included grocery trucks, tanker trucks, refuse haulers, school buses, and transit buses. Over the one-year demonstration period, DPF-equipped vehicles accumulated over 3,525,000 miles without any major incidents attributed to the DPFs or the low sulfur diesel fuel. Most of the grocery trucks and all of the tanker trucks accumulated over 100,000 miles of operation between test rounds. Diesel PM emission reductions were maintained after one year, with no signs of deterioration. The test vehicles retrofitted with passive DPFs and fueled with low sulfur diesel had over 90 percent lower PM emissions when compared to control vehicles with factory mufflers and operated on ARB diesel fuel.

Experience with Diesel Oxidation Catalysts

This technology is commercially available and devices have been installed on tens of thousands of mobile diesel-fueled engines. As a result of the U.S. EPA's Urban Bus Retrofit/Rebuild program, several DOC models have been certified by the U.S. EPA and through ARB's aftermarket parts certification program. Nationwide, thousands of DOCs are installed on urban transit buses with engines older than 1994. In general, DOCs functioned well on all of these vehicles.

Experience with 0.01 g/bhp-hr Engines

Repowering engines is a widespread practice by owners of heavy-duty trucks to extend the useful life of an expensive vehicle. So far there is little experience with a new engine certified to 0.01g/bhp/h PM emission standard, because the certification standard for truck engines is not required until 2007. Detroit Diesel Corporation, Caterpillar, Cummins and International have each certified engines to the California urban bus standard of 0.01 g/bhp-hr, by using a DPF to achieve the low PM standard.