

Impacts of Freight Transportation on Regional Emissions

By

Jeffrey Ang-Olson

ICF Consulting, Inc.

60 Broadway

San Francisco, CA 94111

W. Seth Hartley

ICF Consulting, Inc.

60 Broadway

San Francisco, CA 94111

Diane Turchetta

Federal Highway Administration

400 7th St., S.W.

Mailcode: HEPN-10, Room 3240

Washington, DC 20590

December 20, 2005

ABSTRACT

Robust growth in freight transportation activity, coupled with relatively less stringent regulation on emissions from the freight sector, has led to increased concerns about the effect of freight movement on regional air quality. Most existing emission inventories do not distinguish between freight and non-freight activity. This study, conducted for the Federal Highway Administration, examines criteria pollutant emissions that result from freight transportation in six large metropolitan areas (Baltimore, Chicago, Dallas-Fort Worth, Detroit, Houston, and Los Angeles). This paper develops estimates of emissions from four freight modes: trucking, freight rail, waterborne freight (including marine vessels and port cargo handling equipment), and air freight (including aircraft and airport ground support equipment). The emissions estimates are based partly on existing emission inventory data and partly on new estimates by the authors. The study finds that the contribution of freight transportation to regional emissions totals varies considerably between metropolitan areas. There is also wide variation in the sources of regional freight transportation emissions.

INTRODUCTION

The contribution of freight transportation to air pollution is a growing concern. Environmental and transportation agencies have focused for decades on reducing air pollutant emissions from light duty passenger vehicles, with unquestionable success. Today, the passenger vehicle sector (automobiles and light trucks) produces 60 percent fewer smog-forming pollutants than it did 20 years ago, despite a 77 percent rise in vehicle miles traveled (VMT). (U.S. EPA, 2005) (U.S. Federal Highway Administration, 2003)

In contrast, pollutant emissions from freight transportation sources have, in some cases, remained fairly constant over the last 20 years or have actually risen. This trend can largely be attributed to two factors. One is the relatively less stringent regulation on emissions from the freight sector. Although EPA has recently issued strict new emission standards for heavy-duty trucks, these standards do not begin to take effect until 2007, and then will take some time to ripple throughout the nation's truck fleet. The major non-road freight modes (locomotives, marine vessels) were virtually unregulated until the late 1990s, and today remain much less regulated than on-road sources. Slow turnover of the non-road freight fleet means that these sources will contribute an increasingly large share of mobile source emissions.

The second factor is the robust growth in freight transportation activity. Since deregulation in 1980, the trucking industry has evolved to become highly responsive and flexible, meeting industry demands for more frequent and reliable shipments. As a result, growth in heavy-duty truck VMT has outpaced passenger vehicle VMT, and despite a shift toward a more service-

oriented economy, trucking ton-miles have grown in pace with the nation's gross domestic product. Some components of non-road freight are growing even faster than trucking. Air cargo is the fastest growing freight sector, with domestic air cargo ton-miles increasing more than 5 percent annually between 1980 and 2003. (U.S. Bureau of Transportation Statistics, 2004)

Railroad ton-miles have increased 2.3 percent since 1980, and rail intermodal shipments grew by 5.2 percent during that period. (American Association of Railroads, 2004) Domestic waterborne ton-miles on the whole are declining, in response to reduced bulk commodity shipments. But container movements at some of the nation's largest ports are growing at an astounding pace. For example, container traffic through the Port of Los Angeles has nearly doubled in just the last five years. (Port of Los Angeles, 2004)

These trends mean that freight is becoming a more significant source of urban air pollution. And at the same time, there is a heightened concern about the health effects of diesel engine emissions. Most freight trucks, locomotives, and ships are powered by diesel engines, which are a major source of emissions of nitrogen oxides (NO_x) and particulate matter (PM). These health concerns, and the implementation of the 8-hour ozone and fine particulate standards, will require many regions across the country to find new ways to control NO_x and PM emissions.

This study is intended to help fill a void in the current understanding of the air quality impacts of freight transportation. A large body of research has looked at multimodal freight flows from a transportation and economic perspective, and many other studies have examined the air quality impacts of freight transportation for a single mode. A smaller number of studies have compared efficiency or emissions across two or more freight modes in an intercity context. But very few

studies have examined freight transportation and emissions in urban areas. Emission inventories prepared for air quality planning purposes typically do not distinguish between freight and non-freight activity and may not allow comparison across modes or cities.

This paper discusses freight transportation emissions in six metropolitan areas (Baltimore, Chicago, Dallas-Fort Worth, Detroit, Houston, and Los Angeles). Emission estimates are presented for the following freight modes: trucking, freight rail, marine freight vessels, port cargo handling equipment, air freight, and freight-related airport ground support equipment. The report draws on a variety of existing studies and data sources, and develops new emissions estimates to fill some data gaps.

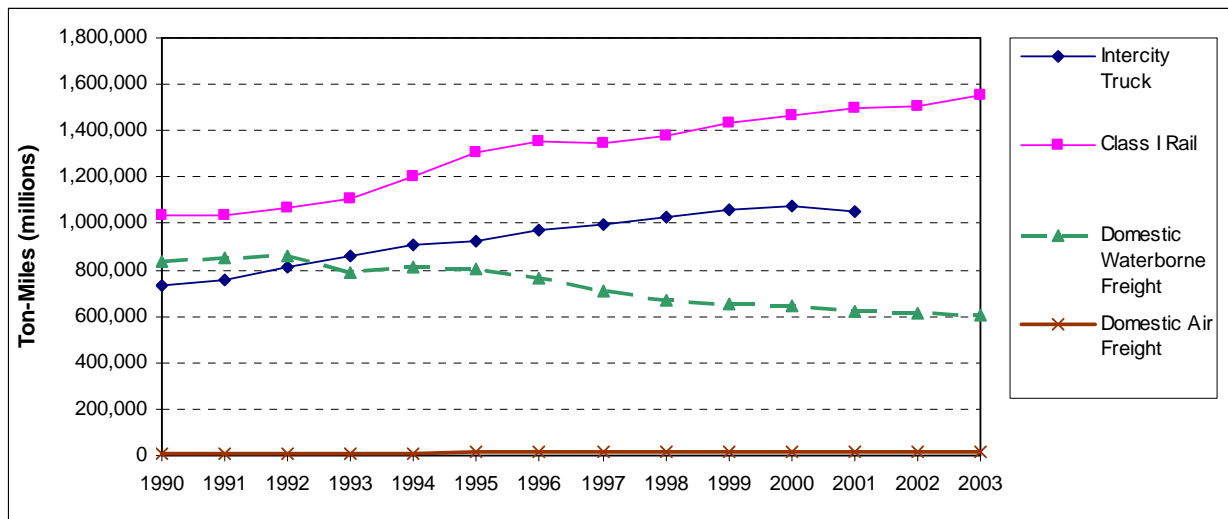
BACKGROUND

Although the U.S. economy is becoming more service-oriented, demand for freight transportation has been rising steadily, and forecasts show continued growth at least over the next several decades. In 2001, the Bureau of Transportation Statistics reports that more than 3.2 trillion ton-miles of freight were moved over the nation's domestic transportation system, up almost 22 percent from the 2.6 trillion ton-miles of freight moved in 1990, an annual growth rate of 2.0 percent. (U.S. Bureau of Transportation Statistics, 2004) On a ton-mile basis, most U.S. domestic freight moves by rail (47 percent) and truck (32 percent). On a value basis, trucking accounts for three-quarters of freight shipments.

Figure 1 depicts trends in domestic ton-miles for the four primary freight modes. This figure illustrates rising volumes for the intercity truck and rail modes, and declines in domestic

waterborne freight. Air freight, which appears flat in Figure 1 due to the scale of the graph, has actually increased 65 percent since 1990.

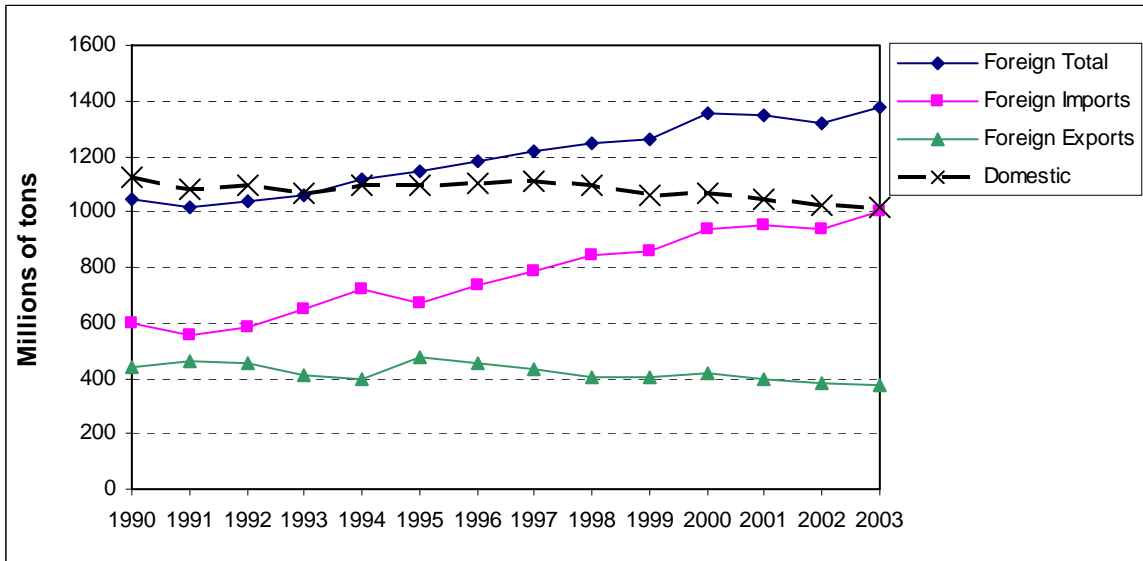
Figure 1: Domestic Freight Ton-Miles, 1990 – 2003



Source: Bureau of Transportation Statistics. (2004) *National Transportation Statistics*. Intercity truck data not available for 2002 and 2003.

The domestic waterborne freight tonnage in Figure 1 can be a misleading indicator of trends in the waterborne sector because more than half of U.S. waterborne freight tonnage is international. On a tonnage basis, waterborne freight has been increasing due to the rapid growth in U.S. imports. While domestic waterborne tonnage fell 9 percent between 1990 and 2003 and U.S. waterborne export tonnage fell by 15 percent, waterborne imports grew by 67 percent over that period. (U.S. Army Corps of Engineers, 2003) As a result, total waterborne freight tonnage has actually increased since 1990 by approximately 11 percent. Figure 2 illustrates these trends.

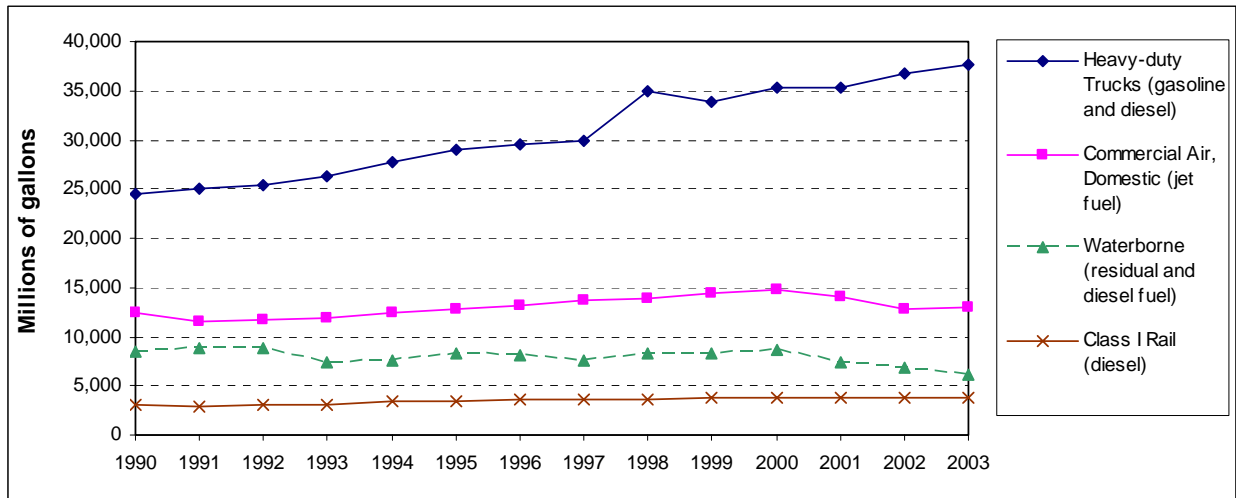
Figure 2: Waterborne Freight Tonnage, 1990 – 2003



Source: U.S. Army Corps of Engineers. (2003) *Waterborne Commerce of the United States*.

Fuel use is generally proportional to emissions of greenhouse gases. While freight trucks, locomotives, marine vessels, and aircraft are becoming more fuel-efficient over time, growth in freight activity has generally outpaced these efficiency improvements. Consequently, freight fuel use has been increasing in the trucking and rail sectors. Figure 3 illustrates these trends in fuel consumption. (Note that most commercial aircraft fuel use in this figure is due to passenger movements.)

Figure 3: Fuel Consumption by Domestic Freight Mode, 1990 – 2003



Source: Bureau of Transportation Statistics. (2004) *National Transportation Statistics* (air, waterborne, rail); Federal Highway Administration. (2003) *Highway Statistics* (truck).

EPA develops a National Emission Inventory (NEI) that reports emissions by source type. Table 1 shows NEI estimates of U.S. NO_x and PM-10 emissions from the four major freight modes for 2002. The NEI does not distinguish between freight and non-freight activity. Table 1 shows that trucking, rail, commercial marine, and aircraft together account for approximately half of mobile source NO_x emissions and 27 percent of all U.S. NO_x emissions. (U.S. EPA, 2005) These sources account for 37 percent of mobile source PM-10 emissions and less than 1 percent of all U.S. PM-10 emissions. (The vast majority of PM-10 emissions come from agricultural fields, wildfires, and fugitive dust.)

Table 1: U.S. NO_x and PM-10 Emissions by Transportation Mode, 2002

Mode	NO _x Emissions				PM-10 Emissions			
			Percent of:				Percent of:	
	Tons	Percent	All Mobile Sources	Total	Tons	Percent	All Mobile Sources	Total
Heavy-duty Vehicles	3,782,000	65.6%	33.0%	17.9%	120,000	63.5%	23.3%	0.5%
Railroads	889,000	15.4%	7.8%	4.2%	22,000	11.6%	4.3%	0.1%
Comm. Marine Vessels	1,011,000	17.5%	8.8%	4.8%	44,000	23.3%	8.5%	0.2%
Aircraft	81,000	1.4%	0.7%	0.4%	3,000	1.6%	0.6%	0.0%
Total	5,763,000	100%	50.3%	27.3%	189,000	100%	36.7%	0.9%

Source: U.S. EPA. (2005) National Emissions Inventory (NEI) Air Pollutant Emissions Trends Data.

FREIGHT TRANSPORTATION EMISSIONS IN METROPOLITAN AREAS

We estimated emissions from freight transportation sources in the Baltimore, Chicago, Dallas-Fort Worth, Detroit, Houston, and Los Angeles metropolitan areas. We developed these estimates using a combination of emission inventory data provided by state air quality agencies and metropolitan planning organizations (MPOs) and our own calculations. The emissions estimates were generally developed for the 1-hour ozone nonattainment or maintenance area; in the case of the Los Angeles region, we defined the region as the South Coast Air Quality Management District and Ventura County nonattainment areas.

Table 2 shows the population, land area, and population density of these regions. The Los Angeles region has a much larger population than the other regions – nearly twice that of the Chicago region, the next most populous. Population density is greatest in the Chicago and Los Angeles regions; the Houston region has by far the lowest population density.

Table 2: Population Density of the Six Study Regions, 2002

Region	2002 Population	Land Area (sq miles)	Population Density (persons/sq mile)
Baltimore	2,556,159	2,237	1,143
Chicago	8,240,743	3,690	2,233
Dallas-Ft. Worth	5,337,367	3,480	1,534
Detroit	4,870,180	4,521	1,077
Houston	4,920,948	7,707	639
Los Angeles	15,946,719	8,327	1,915

Note: Area defined as 1-hour ozone nonattainment or maintenance area; figures for Chicago region exclude portion of Kendall County within the nonattainment area; figures for Los Angeles represent South Coast Air Quality Management District and Ventura County nonattainment areas.

Source: U.S. Bureau of the Census (2004); California Air Resources Board. (2004) *Almanac, Appendix D* (Los Angeles region data).

The remainder of this section is organized by the four major freight modes: trucking, freight rail, marine freight, and air freight. Each sub-section briefly discusses the methodology used to develop the emissions estimates, followed by the results.

Trucking Emissions

Trucking emissions are typically calculated as part of the total on-road vehicle emissions estimation process. Because on-road vehicles are one of the largest sources of pollutant emissions, and because of transportation conformity requirements under the Clean Air Act, the process for estimating on-road vehicle activity and emissions is often more comprehensive and complex than for other transportation sources. All large metropolitan areas develop detailed estimates of VMT and on-road emissions by vehicle class and roadway functional class.

In most cases, we report the 2002 on-road inventory data developed by the MPO or state air quality agency for each region, typically developed as required by EPA's Consolidated Emissions Reporting Rule (CERR). In the case of Baltimore, a 2002 annual inventory was not available, so we estimated annual on-road emissions based on 2002 daily emissions calculated by the MPO for conformity purposes.

The five study regions outside California use a similar methodology to estimate on-road vehicle emissions. This methodology typically involves the following steps; some MPOs may perform these steps in a slightly different order.

1. A regional travel demand model is used to estimate base and future year traffic volumes by link, sometimes developing separate estimates of truck and passenger vehicle volumes.
2. The model traffic volumes are adjusted based on observed traffic counts from the Highway Performance Monitoring System (HPMS), possibly supplemented with additional traffic counts.
3. Estimates are made of traffic volumes on local roads not represented in a travel model. In some cases this is done by the local MPOs; others rely on local roadway VMT provided by the state DOT.
4. Daily traffic volumes are disaggregated by link into hourly volumes using observed traffic counts.
5. Model traffic volumes at the link level are allocated to major vehicle types, based on traffic count information.

6. VMT is summed by vehicle type and facility type.
7. VMT is apportioned into the 16 vehicle types required by MOBILE6. (California's EMFAC model uses three weight classes for trucks divided into gasoline catalyst, gasoline non-catalyst, and diesel engines.)
8. Hourly speeds are estimated for each link, and VMT is then grouped into 14 speed "bins" for each roadway functional class.
9. MOBILE6 input scripts are developed for information such as fuel Reid vapor pressure (RVP), engine tampering levels, inspection and maintenance programs, and vehicle emission standards.
10. VMT is multiplied by the appropriate emission factors to determine emissions.

Table 3 presents a comparison of heavy-duty truck emissions in the six study regions. Figures in bold reflect the highest truck percentage among the six regions. The regions show some significant differences in terms of the relative contribution of trucks to total on-road pollutant emissions. The contribution of freight trucks to total on-road NO_x emissions ranges from a high of 63 percent (Detroit) to a low of 49 percent (Los Angeles). The contribution of freight trucks to total on-road PM-10 emissions ranges from a high of 63 percent (Chicago and Detroit) to a low of 31 percent (Los Angeles).

A number of factors contribute to the differences seen in Table 3. Some industry sectors are more transportation intensive than others, so differences in regional economic structure create different levels of trucking activity. Differences between Los Angeles and the other regions are caused in part by differences in the Mobile and EMFAC emission factors. Some of the emissions

differences may also be caused by differences in the composition of the truck fleet. For example, in the Los Angeles region, gasoline trucks account for the largest share of total truck VMT (32 percent), which means that truck VOC and CO emissions are relatively larger in Los Angeles. Regions with more pass-through truck traffic will tend to have a larger share of Class 8b truck VMT (diesel powered), since long-haul trucks tend to be larger combination vehicles, and therefore higher NO_x and PM emissions.

Table 3: Comparison of Heavy-Duty Truck Emissions in the Six Study Regions, 2002

Region	NO _x as % of total (tons) on-road NO _x		VOC as % of total (tons) on-road VOC		PM-10 as % of total (tons) on-road PM-10		CO as % of total (tons) on-road CO	
Baltimore	29,081	50%	1,416	6%	734	56%	13,232	4%
Chicago	96,291	57%	6,500	11%	2,641	63%	58,330	6%
Dallas-Ft. Worth	53,718	50%	2,174	4%	884	38%	20,229	2%
Detroit	98,195	63%	5,374	9%	2,382	63%	62,805	6%
Houston	64,590	55%	2,408	6%	1,256	48%	20,117	3%
Los Angeles	130,341	49%	14,839	11%	2,210	31%	121,776	9%

Freight Railroad Emissions

The standard approach for calculating railroad emissions is generally the most simplistic, and potentially the least accurate, of the four major freight modes. This is because, unlike other freight transportation modes, which rely on publicly-owned facilities, there is typically little or no published information on private railroad activity available for specific regions. Thus, state and regional air quality agencies must make do with the often limited railroad activity data available directly from the railroad companies.

To determine freight rail emissions in the six study regions, we relied on data provided by state air quality agencies. In some cases, we modified or supplemented state emissions estimates; in other cases, we report the state figures as provided. All six study regions follow a similar methodology to estimate railroad emissions. This involves estimating county-level fuel use for line-haul locomotives and, separately, for switch yard locomotives. Fuel use estimates are then used to calculate emissions. For each region, we report only emissions associated with freight railroads; no passenger railroad emissions are included.

The steps in this approach are outlined below. The details of the methodology (and its accuracy) depend heavily on the nature of the locomotive activity data provided to the states by the railroads.

1. For each freight railroad operating in the state, statewide line-haul locomotive fuel use is apportioned to counties in direct proportion to the gross tons-miles (GTM) by county.
2. In cases where railroads are not able to report GTM, air quality agencies use mileage of active track as a proxy.
3. Switch yard locomotive fuel use is calculated by applying an annual fuel consumption rate to the number of switch yard locomotives.
4. Class II and III railroads (shortline and switching railroads) are often unable to provide the information described above. In this case, fuel consumption is estimated by obtaining the number of employees of the railroad by county using a commercial employment database and a ratio of fuel consumption per employee.

5. The fuel use estimates for each railroad are summed. The result is an estimate of total railroad fuel use by county.
6. Emission factors (in grams per gallon) are applied to the fuel use figures to estimate annual emissions. Some states use locomotive emission factors from EPA's 1992 emission inventory guidance (U.S. EPA, 1992), although these emission factors are likely outdated. In cases where we were able to obtain fuel use data (Baltimore, Dallas, Houston), we calculated emissions using 2002 emission factors provided in EPA's 1998 Regulatory Support Document. (U.S. EPA, 1998)

Table 4 shows the freight rail emissions totals in the six study areas. Chicago has far more freight rail emissions than any other region – approximately twice the emissions in the Los Angeles region and more than four times that in any of the other regions. Table 4 also shows the significant regional differences in the contribution of switch yard locomotive activity to the freight rail emissions total. In Baltimore, for example, switchers are estimated to be responsible for more than half of the freight rail emissions. In contrast, switcher locomotives in the Los Angeles region contribute only 10 percent of NO_x and 8 percent of PM-10 from freight rail, according to the region's emission inventory. Some of these differences may be a product of variations in the inventory development methods.

Table 4: Freight Rail Emissions in the Six Study Areas, 2002

Region	NO _x		VOC		PM-10		CO	
	tons	% switch yard	tons	% switch yard	tons	% switch yard	tons	% switch yard
Baltimore	2,655	54%	136	63%	71	52%	289	53%
Chicago	23,212	18%	1,098	23%	792	32%	2,568	17%
Dallas	4,157	27%	193	35%	113	26%	459	26%
Detroit	2,106	25%	102	32%	58	23%	230	24%
Houston	5,163	31%	243	38%	141	29%	569	30%
Los Angeles	12,744	10%	641	10%	346	8%	2,282	8%

Marine Freight Emissions

Marine freight includes shipping to and from U.S. coastal ports, in the Great Lakes, and in navigable inland waterways. Marine freight-sector emissions are caused by the engines used to power vessels and associated equipment, and by engines in the land-based equipment at ports that are used for handling marine cargo. Sea-side emissions are due to freight shipping vessels ranging from non-self-propelled barges and scows to self-propelled container ships, bulk carriers, tankers, and tugboats. Land-side emissions come from on-dock cargo-handling equipment, trucks, and locomotives. Emissions from on-road trucks and locomotives at ports are captured in the estimates of the emissions from the trucking and railroad sectors, respectively, and are not included here. On-dock cargo-handling equipment includes the equipment used to load and unload freight from ships, service the ships, and move freight within the port area, such as yard tractors, forklifts, and cranes. We estimated emissions associated with these activities for each major port in the six study regions.

The process for estimating marine vessel emissions involves five general steps:

1. Collecting data on the number of vessel trips at a port by vessel type (e.g., container ship, tanker, barge, etc.)
2. Determining the amount of time each vessel type spends in different operating modes (e.g., open water cruise, reduced speed zone, in-port maneuvering, at-dock hoteling)
3. Determining the amount of power consumed (in kilowatts) by vessel type and operating mode
4. Determining emission factors (in the form of grams per kW)
5. Calculating emissions (by vessel type and operating mode) by multiplying 1 x 2 x 3 x 4

The Port of Los Angeles and Houston have recently developed marine vessel emission inventories. We report these emissions estimates, scaling to 2002 as necessary. For the other ports in the study regions, we estimated vessel emissions using a combination of EPA guidance, methodologies and data from other studies, and published current port activity data. Our inventories for the ports of Baltimore, Chicago, and Detroit are developed primarily based on the methodologies laid out in reports for EPA by ARCADIS (1999a and 1999b) and Environ (2002), and use parameters developed for the most recent emissions study for the Port of Los Angeles. (Starcrest Consulting Group, 2004a) For the Port of Long Beach, we estimated vessel emissions based on the Port of Los Angeles inventory and the ratios of cargo tonnage between the two ports. For every port, we report only emissions associated with freight vessels and harbor vessels that primarily assist in freight movement (e.g., tugboats); no cruise ship or passenger ferry emissions are reported.

No EPA guidance or other standardized methodology exists for developing estimates of port cargo handling equipment (CHE) emissions. For the ports of Houston, Los Angeles, and Long Beach, we used the recent CHE inventories developed for the ports by Starcrest (2004a, 2004b, 2004c). For the other study ports, we developed a methodology that relies on the Los Angeles and Long Beach CHE emission inventories and scales emissions using appropriate cargo tonnage. Table 5 summarizes the methods used for estimating vessel and CHE emissions at the study ports.

Table 5: Summary of Marine Freight Emissions Estimation Process

Port	Vessel Emissions	Cargo Handling Equipment Emissions
Port of Baltimore	Determined 1996 emissions using ARCADIS (1999a) and Environ (2002), and scaled to 2002 based on growth in trips.	Based on Port of Los Angeles and Long Beach CHE inventories and ratios of marine tonnage.
Port of Chicago	Determined 1995 emissions using ARCADIS (1999b) and Environ (2002), and scaled to 2002 based on growth in trips.	Based on Port of Los Angeles and Long Beach CHE inventories and ratios of marine tonnage.
Port of Detroit	Determined 1995 emissions using ARCADIS (1999b) and Environ (2002), and scaled to 2002 based on growth in trips.	Based on Port of Los Angeles and Long Beach CHE inventories and ratios of marine tonnage.
Port of Houston, Port of Galveston, Port of Texas City, Port of Freeport	Interpolated 2002 emissions using 1997 and 2007 values from Starcrest (2000) for each waterway section.	Houston: based on 2001 CHE inventory, scaled to 2002 based on marine tonnage. Galveston, Texas City, Freeport: Based on Port of Los Angeles and Long Beach CHE inventories and ratios of marine tonnage.
Port of Los Angeles	Used emissions from 2001 vessel inventory, scaled to 2002 based on tonnage.	Used emissions from 2001 CHE inventory, scaled to 2002 based on tonnage.
Port of Long Beach	Scaled from 2002 Port of Los Angeles inventory using ratios of cargo tonnage.	Used values from 2002 CHE inventory.

Table 6 shows total freight-related emissions from marine vessels and port CHE in the ports of the six regions of study. The Los Angeles region has by far the greatest marine freight emissions – more than 22,600 tons of NO_x and more than 1,500 tons of PM-10 annually. The Houston

metropolitan area has more than 14,000 tons of NOx and more than 900 tons of PM-10 annually from marine freight. Marine freight emissions in the other three regions are smaller – approximately 3,300 tons of NOx in Baltimore, 2,200 tons of NOx in Chicago, and 500 tons of NOx in Detroit. The Port of Houston has the greatest marine vessel emissions of any single port, followed closely by the Ports of Long Beach and Los Angeles.

Port CHE emissions are greatest at the Port of Long Beach, followed by the Port of Los Angeles. CHE emissions make up approximately 20 percent of the marine freight total at these ports. At the Port of Houston, CHE emissions are only about 10 percent of the marine freight total. This difference reflects differences in the freight handled at the ports – Houston handles a large proportion of liquid bulk freight (mostly petroleum), which requires relatively little in terms of land-side CHE, while Los Angeles and Long Beach handle large volumes of containers, which require extensive land-side activity by CHE.

Table 6: Total Marine Freight Vessel and Port CHE Emissions by Port

Region	Port	Marine Freight Vessel Emissions		Port CHE Emissions		Port Total Freight Emissions	
		NOx	PM-10	NOx	PM-10	NOx	PM-10
Baltimore	Port of Baltimore	2,399	141	916	50	3,315	190
Chicago	Port of Chicago	1,901	160	298	13	2,199	173
Detroit	Port of Detroit	247	18	221	9	468	27
Houston	Port of Houston	10,576	694	1,011	74	11,587	769
	Port of Galveston	403	21	179	9	582	30
	Port of Freeport	461	20	228	12	688	32
	Port of Texas City	1,294	73	200	10	1,494	84
	Sub-total	12,734	808	1,618	106	14,351	915
Los Angeles	Port of Los Angeles	8,687	614	1,892	113	10,579	728
	Port of Long Beach	9,660	647	2,371	147	12,031	794
	Sub-total	18,347	1,261	4,263	260	22,610	1,521

Table 7 shows a comparison of the NOx emissions from port CHE for the three ports that were able to provide CHE emissions by equipment type. Yard tractors make up the largest component of port CHE emissions in all cases. This comparison shows that, while yard tractor emissions are similar at the Ports of Los Angeles and Long Beach, emissions from handlers/loaders and from cranes are significantly higher at Long Beach. Emissions from yard tractors and handlers/loaders are relatively smaller at the Port of Houston than at the Southern California ports, reflecting the relatively small share of containerized cargo at Houston.

Table 7: Comparison of Port CHE NOx Emissions by Port

CHE Type	Port of Los Angeles		Port of Long Beach		Port of Houston	
	NOx tons	percent	NOx tons	percent	NOx tons	percent
Yard Tractors	1,475	78%	1,409	59%	459	45%
Forklifts	92	5%	141	6%	244	24%
Handlers/Loaders	228	12%	363	15%	120	12%
Cranes	72	4%	365	15%	101	10%
Other	25	1%	93	4%	86	9%
Total	1,892	100%	2,371	100%	1,011	100%

Air Freight Emissions

Emissions from air freight are generated by aircraft and by airport ground support equipment. Aircraft include those devoted exclusively to cargo and passenger aircraft that carry freight together with passenger baggage in the cargo space (belly cargo). Airport ground support equipment include aircraft and baggage tow tractors, ground power units, portable aircraft air conditioning units, and air start units, as well as medium and light-duty trucks for such operations as refueling and de-icing. Over the past decade, many of the nation's airports have been working to electrify GSE, and as a result, GSE emissions are dropping significantly. We estimated ground support equipment emissions attributable to freight based on the same fractions used in determining the aircraft emissions associated with freight.

A typical airport emission inventory includes aircraft emissions that occur at ground level up to 3,000 feet. Aircraft exhaust emissions are calculated for one complete landing and takeoff (LTO) cycle for each aircraft type, using emissions factors for the aircraft's specific engines at each power setting or mode of operation, as well as the time spent in each mode. The activity of

aircraft for the inventory period can then be multiplied by emission factors to calculate the total emissions. All regions use the FAA-sponsored Emissions and Dispersion Modeling System (EDMS) to develop emission inventories for airports. We obtained annual emission estimates from the most recent application of the EDMS model for airports handling at least five percent of a region's air cargo. This includes the major passenger airport in each region plus the Ontario airport in the Los Angeles region and the Alliance airport in the Dallas-Ft Worth region.

The EDMS model does not distinguish between freight and non-freight movement (passengers). To segregate these sectors, we developed an approach that allocates each airport's total commercial aircraft emissions to the freight and non-freight sectors. We obtained aircraft departure records from the BTS Air Carrier Statistics database and assumed emissions from air cargo aircraft are attributable entirely to freight. Air cargo aircraft accounted for 0.4 to 7.0 percent of departures at all airports except Alliance Airport in Fort Worth (AFW), which almost exclusively handles air cargo. For passenger aircraft departures, we estimated the weight of the aircraft's freight, passengers, and baggage (using an average weight per passenger of 240 lbs, based on a FAA sponsored survey in 2003), and used these percentages to allocate emissions. By this method, we estimated that freight is responsible for 1.4 to 6.7 percent of passenger aircraft emissions at the study airports. In total, we estimated that the air freight share of aircraft emissions ranges from a low of 2.3 percent at Detroit to a high of 10.9 percent at LAX, among the study airports with passenger service (the exception being AFW, which is nearly 100 percent freight).

Because the EDMS model does not estimate PM emissions for aircraft, we estimated the ratio of aircraft PM to SO_x emissions using data from the Southern California Ozone Study (California Air Resources Board, 1997), and multiplied this ratio by the SO_x emissions at each airport.

Table 8 summarizes the aircraft emissions attributable to air freight movement for five criteria pollutants. LAX has by far the largest freight emissions among the eight study airports. Aircraft emissions of VOC, NO_x, and CO in the Los Angeles region are approximately 70 percent more than the next largest region (Chicago). Emissions of SO_x (and PM-10, which we calculated from the SO_x emissions) are proportionally lower for the Los Angeles airports, most likely due to the use of jet aircraft fuel with lower sulfur content, as required in California.

Table 8: Aircraft Freight-Related Emissions, 2002

Region	Airport	Emissions (tons per year)				
		VOC	NO _x	CO	SO _x	PM-10
Baltimore	BWI	3.0	19.7	25.3	1.9	0.6
Chicago	ORD	37.7	347.3	222.5	21.9	6.8
Dallas-Ft Worth	DFW	9.6	47.8	54.9	4.6	1.4
	AFW	26.5	69.3	76.7	4.8	1.5
	Total	36.1	117.2	131.5	9.4	2.9
Detroit	DTW	8.7	29.5	80.5	3.6	1.1
Houston	IAH	5.7	53.1	59.4	5.0	1.5
Los Angeles	LAX	70.1	615.4	416.4	22.1	6.9
	ONT	6.0	80.9	59.4	2.8	0.9
	Total	76.1	696.3	475.8	24.9	7.7

Table 9 shows ground support equipment (GSE) emissions attributable to air freight movement for the same pollutants. We obtained GSE emissions from each state or regional air quality agency and allocated a portion to freight using the same methodology and ratios as for aircraft. GSE emissions for Detroit (DTW) and Alliance (AFW) were not unavailable from air quality agencies. For DTW, we estimated GSE emissions by multiplying Chicago (ORD) GSE emissions by the ratio of air freight activity at DTW to ORD. For AFW, we estimated GSE emissions by multiplying the DFW GSE emissions by the ratio of air freight activity at AFW to DFW.

Table 9: Airport Ground Support Equipment Freight-Related Emissions, 2002

Region	Airport	Emissions (tons per year)				
		VOC	NO _x	CO	SO _x	PM-10
Baltimore	BWI	3.6	4.8	90.1	0.4	0.2
Chicago	ORD	2.2	17.8	24.8	0.3	1.3
Dallas-Ft Worth	DFW	3.8	13.3	158.9	0.4	0.4
	AFW	0.4	1.3	16.1	0.0	0.0
	Total	4.2	14.6	175.0	0.4	0.4
Detroit	DTW	0.5	4.2	5.8	0.1	0.3
Houston	IAH	2.1	6.8	87.4	0.2	0.2
Los Angeles	LAX	14.8	102.5	183.4	0.4	4.3
	ONT	2.5	17.7	31.6	0.1	0.7
	Total	17.3	120.2	215	0.5	5

The results in Table 9 show that LAX has again by far the largest air freight-related emissions of NO_x and PM from GSE among the eight study airports. In all airports, NO_x and PM-10

emissions from GSE are generally much less than the freight aircraft emissions of those pollutants, typically less than 20 percent of the aircraft emissions. The high CO emissions reflect the use of gasoline fuel in much of the ground support equipment.

SUMMARY AND CONCLUSIONS

Table 10 shows a comparison of freight transportation NOx emissions by mode. Emissions are greatest in magnitude in Los Angeles, followed by Chicago and Detroit. NOx emissions from freight in the Los Angeles region are nearly five times those in Baltimore and nearly three times those in Dallas-Fort Worth.

Table 10 clearly shows the dominant role of trucking in urban freight movement and emissions. Heavy-duty trucks are responsible for more than three-quarters of freight emissions in all six regions. In Detroit and Dallas-Fort Worth, trucking accounts for virtually all freight emissions – 97 percent of the freight total in Detroit and 93 percent in Dallas-Fort Worth.

In other modes, the regions show considerable diversity in terms of freight emissions. Freight rail NOx emissions in Chicago are nearly twice that in any other region and make up almost 20 percent of Chicago's total freight emissions. In the other five regions, freight rail accounts for less than 10 percent of the total.

Marine freight NOx emissions are greatest in the Houston region, where they account for 17 percent of the freight total, and in the Los Angeles region, where they account for 14 percent of the total. Air freight emissions are dwarfed by the other modes in all six regions. Air freight NOx

emissions are greatest in the Los Angeles region, making up 0.5 percent of the region's freight total.

Table 10: NOx Emissions from Freight by Mode, 2002

Region	Trucking		Freight Rail		Marine Freight		Air Freight		Freight Total	
	NOx tons	%	NOx tons	%	NOx tons	%	NOx tons	%	NOx tons	%
Baltimore	29,081	83%	2,655	8%	3,315	9%	26	0.1%	35,078	100%
Chicago	96,291	79%	23,212	19%	2,199	2%	462	0.4%	122,164	100%
Dallas-Ft. Worth	53,718	93%	4,157	7%	0	0%	155	0.3%	58,030	100%
Detroit	98,195	97%	2,106	2%	468	0%	40	0.0%	100,809	100%
Houston	64,590	77%	5,163	6%	14,351	17%	85	0.1%	84,189	100%
Los Angeles	130,341	78%	12,744	8%	22,610	14%	870	0.5%	166,564	100%

Table 11 shows the comparison of freight transportation PM-10 emissions across modes.

Trucking is still the largest contributor, though less dominant than with NOx emissions. In particular, marine freight accounts for a major portion of freight PM-10 emissions in regions with large seaports – 40 percent of the total in Houston, 37 percent in Los Angeles, and 19 percent in Baltimore. This in part reflects the high PM emission rates of large marine vessels that burn residual fuel and have little or no emission controls.

Table 11: PM-10 Emissions from Freight by Mode, 2002

Region	Trucking		Freight Rail		Marine Freight		Air Freight		Freight Total	
	PM-10 tons	%	PM-10 tons	%	PM-10 tons	%	PM-10 tons	%	PM-10 tons	%
Baltimore	734	74%	71	7%	190	19%	1	0.1%	996	100%
Chicago	2,641	73%	792	22%	173	5%	10	0.3%	3,616	100%
Dallas-Ft. Worth	884	88%	113	11%	0	0%	4	0.4%	1,002	100%
Detroit	2,382	96%	58	2%	27	1%	2	0.1%	2,469	100%
Houston	1,256	54%	141	6%	915	40%	2	0.1%	2,314	100%
Los Angeles	2,210	54%	346	8%	1,521	37%	14	0.3%	4,091	100%

Table 12 compares annual freight emissions with total emissions (mobile, area, and point sources). Freight accounts for 29 to 39 percent of all NO_x emissions in the study regions (total emissions data was not available for Baltimore). Freight NO_x emissions are highest in absolute terms and in percentage terms in the Los Angeles region, which likely reflects the large contribution from the region's ports.

Freight accounts for 1.0 to 5.8 percent of total PM-10 emissions in the study regions. Freight accounts for the largest share of total PM-10 emissions in the Chicago region, which likely reflects the intensive railroad activity there. Note, however, that the vast majority of PM-10 emissions come from agricultural fields, wildfires, and fugitive dust, so the total PM-10 emissions in the six regions depends in part on the amount of undeveloped land within the nonattainment boundaries.

Table 12: Freight Emissions Compared to Total Emissions, 2002 (tons)

Region	NOx Emissions			PM-10 Emissions		
	Freight	Total	% Freight	Freight	Total	% Freight
Baltimore	35,078	N/A	N/A	996	N/A	N/A
Chicago	122,164	357,978	34%	3,616	62,273	5.8%
Dallas-Ft. Worth	58,030	166,088	35%	1,002	105,326	1.0%
Detroit	100,809	327,422	31%	2,469	114,313	2.2%
Houston	84,189	291,001	29%	2,314	132,387	1.7%
Los Angeles	166,564	425,954	39%	4,091	232,476	1.8%

ACKNOWLEDGEMENT

This research was funded by the U.S. Federal Highway Administration (FHWA). Diane Turchetta was the FHWA project manager. The findings do not necessarily reflect the views of FHWA.

REFERENCES

- ARCADIS Geraghty & Miller. (1999a) Commercial Marine Activity for Deep Sea Ports in the United States. Prepared for U.S. EPA.
- ARCADIS Geraghty & Miller. (1999b) Commercial Marine Activity for Great Lake and Inland River Ports in the United States. Prepared for U.S. EPA.
- California Air Resources Board. (2004) Almanac, Appendix D.
- California Air Resources Board. (1997) Southern California Ozone Study-North American Research Strategy for Tropospheric Ozone.
- Environ International Corporation (2002). Commercial Marine Emission Inventory Development. Prepared for U.S. EPA.
- American Association of Railroads. (2004) Railroad Facts.
- Port of Los Angeles. (2004) unpublished data.
- Starcrest Consulting Group. (2000) Houston-Galveston Area Vessel Emissions Inventory.
- Starcrest Consulting Group. (2004a) Port-Wide Baseline Air Emissions Inventory. Prepared for the Port of Los Angeles.
- Starcrest Consulting Group. (2004b) 2001 Cargo Handling Equipment Emissions Inventory: Methodology Comparison. Prepared for the Port of Houston Authority.
- Starcrest Consulting Group. (2004a) Port-Wide Baseline Air Emissions Inventory. Prepared for the Port of Los Angeles.
- Starcrest Consulting Group. (2004c) Baseline Emissions Inventory: Cargo Handling Equipment, Rail Locomotives, and Heavy-Duty Vehicles. Prepared for the Port of Long Beach
- U.S. Army Corps of Engineers. (2003) Waterborne Commerce of the United States.

U.S. Bureau of Transportation Statistics. (2004) National Transportation Statistics.

U.S. EPA. (1992). "Procedures for Emission Inventory Preparation. Volume VI Mobile Sources."

U.S. EPA (1998). Locomotive Emission Standards, Regulatory Support Document, April.

U.S. EPA. (2005) National Emissions Inventory (NEI) Air Pollutant Emissions Trends Data.

U.S. Federal Highway Administration. (2003) Highway Statistics.