SECTION 1 INTRODUCTION

In response to concerns about the potential health impacts to surrounding communities from Port of Los Angeles (Port) operations, and to provide the Port with a planning document to reduce these impacts, the Port commissioned the preparation of a comprehensive air emissions inventory. The report, published in 2004, documented the emissions from marine vessels, locomotives, heavy duty vehicles, and cargo handling equipment operating within the Port for the baseline year of 2001.[4] The baseline emissions inventory formed the basis for the development, prioritization and implementation of emission control strategies to reduce emissions in line with then Los Angeles Mayor James Hahn's goal of "no net increase." This goal, adopted on 10 October 2004 by the Board of Harbor Commissioners, acting on the request of the Mayor, stated the "goal that there will be no net increase in air emissions or traffic impacts from future Port operations." The comprehensive project launched to work toward this goal has been termed "No-Net-Increase" (NNI).

Several of the many control measures being considered for marine vessels are based upon the use of cleaner fuels in auxiliary and propulsion engines, including the use of low sulfur fuels. This report summarizes the results of a study to evaluate the availability of lower sulfur fuels for use in containerships calling on the Ports of Los Angeles and Long Beach, as well as operational issues, emissions benefits, and emission reduction costs associated with their use. The study was completed in response to part of a settlement agreement between the Port of Los Angeles and the National Resource Defense Council with regard to development of the China Shipping terminal.

At the same time that this study was conducted, the California Air Resources Board (ARB) conducted a similar study to support the development of proposed regulations to reduce the emissions from ship auxiliary engines.[5] Information was shared between the Port of Los Angeles consultant and ARB staff preparing the respective studies. EPA is also planning on conducting a global fuel analysis study.[6]

1.1 Scope

Specifically, the study evaluates the availability of fuel with 2,000 parts per million (ppm) or less (2,000, 1,000, 500, 150 and 15 ppm) sulfur for use in the propulsion and auxiliary engines of commercial container vessels when in coastal waters and at berth.

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[4] Starcrest 2004. Starcrest Consulting Group, LLC, *Port-wide Baseline Air Emissions Inventory*, July 2004, as revised.
[5] Paul Milkey, ARB, Presentation: *Availability of Low-Sulfur Marine Distillates to Fuel Oceangoing Vessel Auxiliary Engines in California Coastal Waters*, 18 May 2005. See: *http://www.arb.ca.gov/msprog/offroad/marinevess/presentations/051805/051805fuelpres.pdf.*
[6] "Air Emissions from Ships" presentation by Bryan Wood-Thomas, EPA, at Texas Commission on Environmental Quality (TCEQ) Maritime Air Technology Workshop, 14 April 2005.

The potential fueling locations that were considered include:

- the Ports of Los Angeles and Long Beach
- all ports of origination and ports of call used by China Shipping vessels that call on Berths 97 – 109 (only Berth 100 is active) in the Port of Los Angeles
- the twenty additional ports most frequently called by vessels that service the Port of Los Angeles

The evaluation includes a survey of the container shipping lines that call on the Ports of Los Angeles and Long Beach to assess the current status of use of low sulfur fuel and the feasibility of using lower sulfur marine fuel on their fleet.

Finally, the evaluation assesses the costs of the various grades of lower-sulfur marine fuel and the cost, per ton of pollutant reduced, for the following pollutants:

- Nitrogen oxides (NO_X)
- Particulate matter (PM_{10})
- Sulfur dioxide (SO_2)
- Carbon dioxide (CO_2)

1.2 Approach

Low sulfur fuels provide an overall emissions benefit when compared with the currently consumed fuels in container vessels calling on the Port and transiting coastal waters. Propulsion and auxiliary engines on container vessels typically use intermediate fuel oil (IFO). According to ARB's recent ship survey, 22% of auxiliary engines are fueled by marine diesel oil (MDO). A smaller percentage of auxiliary engines may be using a lighter distillate fuel, such as marine gas oil (MGO), while at Port. Further information on fuel grades and the current and future regulatory framework in countries of interest are detailed in Section 2.

In evaluating the feasibility of using low sulfur fuels, it is important to assess the availability of these fuels, currently and in the future, at fueling locations for vessels that call on the Port of Los Angeles. For this purpose, a vessel list was extracted from data from the 2004 Marine Exchange of Southern California (MarEx) to identify the China Shipping container vessels calling at Berth 100. Mercator Transport Group (Mercator) was then asked to analyze this and other vessel call data to develop a list of ports that included the China Shipping vessels and the top twenty fuel locations, beyond those serving China Shipping, as described in Section 3.

The ports of call were then grouped into regions to identify refiner and supplier markets, and contacts, including bunker experts, were interviewed as to current and future availability. The contacts were also queried as to expectations and impediments to the supply and marketing of low sulfur fuels, as described in Section 4.

In order to determine the present status of use of lower sulfur fuel, the major container carrier lines calling on the Ports of Los Angeles and Long Beach were contacted and interviewed in coordination with Port of Los Angeles staff. Engine and lubricant manufacturers were also contacted to obtain information about equipment and operational issues. This information is compiled in Section 5.

For cost effectiveness, incremental fuel costs, emissions extracted from the baseline for containerships documented in the Port of Los Angeles' *Portwide Baseline Air Emission Inventory*[7] (PWBAEI), emission reduction percentages and emission reductions were used. Cost effectiveness was estimated by dividing the incremental fuel cost by the emission reductions. Section 6 details the results and assumptions of this analysis.

Section 7 summarizes the conclusions of the study with regard to low sulfur fuel availability, status of use by containership fleets, operational issues, and emissions reductions and cost benefits.

1.3 Report Organization

This report documents the findings of the study as follows:

- Section 2 is a regulatory overview.
- Section 3 identifies the ports of origination and call that were considered.
- Section 4 presents the fuel availability findings, by region.
- Section 5 discusses the status and feasibility of using low sulfur fuels in containership fleets.
- Section 6 presents the emission reduction estimates and provides cost estimates for the various grades of fuel for selected vessel configurations.
- Section 7 presents the conclusions.

[7] Starcrest 2004.

SECTION 2 REGULATORY OVERVIEW

This section provides an overview of the various fuel grades used in marine and landside applications, and discusses the diesel fuel regulatory framework in the United States (U.S.) and abroad.

2.1 Fuel Grades

The International Organization for Standardization (ISO) has developed specifications (ISO 8217) to meet the requirements for marine fuels supplied worldwide for use onboard ships. Out of a total 19 marine fuel categories, four categories or grades are most frequently supplied and used by ships. Industrial names for these four grades are intermediate fuel oil (IFO) 180, IFO380, marine distillate oil (MDO) and marine gas oil (MGO). Residual fuel, IFO380, is the most commonly used fuel for ocean-going vessels (OGV). IFO180 is blended from IFO380 using marine diesel or a gas oil stock. MDO, a distillate, is a blend of gas oil and minor amounts of heavy oil. MGO is gas oil which is clear and not blended with heavy fuel.

In the shipping and bunkering (fuel supply) industries, the terms MDO and MGO are used interchangeably, making it difficult to differentiate between the different grades. In some countries, distillates may be referred to as gas oils. Residual fuel can be called marine diesel fuel, fuel oil, bunker oil, or bunker fuel. For the sake of simplicity, MDO and MGO will be referred to as marine distillate fuel, while the various grades of IFO will be referred to as marine residual fuel.

Within the ISO 8217 specification, marine distillate fuel grades may also be referred to as DMX, DMA, DMB, and DMC. Their characteristics vary and sulfur content and viscosity can be used to distinguish them for purposes of this study:

- DMX – 1.0% sulfur maximum
- DMA – 1.5% sulfur maximum
- DMB – 2.0% sulfur maximum
- DMC – 2.0% sulfur maximum

The DMX specification is limited to diesel fuel for emergency engines capable of cold starting in winter conditions, and is differentiated by its cloud point, flash point and cetane number. DMX is typically sold in 25 or 210 liter drums and is not available in bulk. DMB and DMC have the same sulfur content specification, but DMC has higher viscosity limits. MDO generally corresponds to DMB, and MGO generally corresponds to DMA. There are also marine residual fuel grades (all have a 5.0% sulfur maximum). IFO180 corresponds to RME25, and IFO 380 corresponds to RMG35.[8] The ISO 8217 specifications for intermediate fuel oil and marine distillate fuel are included in Appendix A, Tables A.1 and A.2.

Marine fuels with 2,000 ppm or less sulfur content fall into the marine distillate category, and are used for auxiliary, rather than propulsion, engines. Residual fuel used by ocean-going vessels in propulsion engines does not have sulfur content this low.

[8] *Bunkerworld*, Dr. Vis, Viswa Labs, "Bunker Fuel Grades – How do the four main fuel grades differ from each other?", 2005. See: *http://www.bunkerworld.com/technical/tech_grades.htm*.

American Society for Testing and Materials (ASTM) D975 sets the specifications for seven grades of diesel fuel used by various diesel engine types in the U.S.[9] Diesel Number (No.) 2 is mostly used for onroad (vehicular, automotive) and offroad (harbor craft, locomotives, heavy equipment) engines. CARB Diesel is similar to Diesel No. 2 (S500 or ≤500 ppm sulfur) but it has lower aromatics and higher cetane. ULSD is ultra low sulfur diesel, and has a sulfur content of 15 ppm.

Table 2.1 lists some of the diesel fuels that are available currently and in the near future, including onroad, offroad, marine distillate, and marine residual diesel fuel. The maximum sulfur content is provided in mass percent and parts per million; however, the average or typical sulfur content levels of the diesel fuel produced and supplied are lower than the required maximum sulfur content in order to ensure that the specifications are met. For example, marine residual fuel averaged 28,000 ppm (2.8%) sulfur content worldwide in 2004,[10] even though 50,000 ppm (5%) was the specification limit at that time. The sulfur contents of marine distillate are discussed in detail in Section 4.

The minimum flash point specification for each fuel is included in the table because flash point is of importance relative to legal requirements and safety precautions involved in fuel handling and storage for ships engaged in international voyages. The International Convention for the Safety of Life at Sea (SOLAS) requires that no fuel oil with a flashpoint less than 60 degrees Celsius (°C) be used.[11] The only exception is DMX (used in emergency generators or lifeboat engines), which can have a minimum flashpoint of 43°C.

Table 2.1: Diesel Fuel Maximum Sulfur Content

Name	Category	Common Name	Maximum Sulfur (%)	Maximum Sulfur (ppm)	Minimum Flashpoint (°C)	Availability
Grade No. 2-D S15	Distillate	ULSD	0.0015%	15	52	California and U.S. in 2006
Grade No. 2-D S500	Distillate	CARB/EPA Diesel	0.05%	500	52	Currently available
Grade No. 2-D S5000	Distillate	EPA Offroad	0.5%	5,000	52	Replaced with S500 by 2007
LS MGO (0.1%)	Distillate	MGO	0.1%	1,000	60	New sulfur cap for Europe in 2008
LS MGO (0.2%)	Distillate	MGO	0.2%	2,000	60	Currently available in Europe
DMX	Distillate	MGO	1.0%	10,000	43	Available worldwide
DMA	Distillate	MGO	1.5%	15,000	60	Available worldwide
DMB and DMC	Distillate	MDO	2.0%	20,000	60	Available worldwide
Intermediate Fuel Oil	Residual	IFO/bunker fuel	1.5%	15,000	60	Baltic/North Sea sulfur cap in 2007
Intermediate Fuel Oil	Residual	IFO/bunker fuel	4.5%	45,000	60	Worldwide sulfur cap in 2007
Intermediate Fuel Oil	Residual	IFO/bunker fuel	5.0%	50,000	60	Common for OGV, replaced in 2007

[9] ASTM D975, *Standard Specification for Diesel Fuel Oils*, 2004.
[10] Det Norske Veritas (DNV) Petroleum Services, "MARPOL Annex VI sets Sulphur Test," published in *Lloyds List*, 16 February 2005.
[11] IMO, SOLAS Chapter II-2, Part B, Regulation 4, 2.1.1.

2.2 Regulatory Framework

2.2.1 Marine Fuel Regulations

International

International Maritime Organization (IMO) MARPOL 73/78 Annex VI, Regulations for the Prevention of Air Pollution from Ships, entered into force 19 May 2005. These rules set limits on the NO_X and sulfur oxides (SO_X) emissions by limiting the discharge of NO_X emissions from larger marine diesel engines and by capping the sulfur content of marine residual fuel. The global cap on sulfur content of marine residual fuel has been set at 4.5% (45,000 ppm), with IMO monitoring the worldwide average sulfur content of fuel. Annex VI also contains provisions for SO_X Emission Control Areas (SECA) to be established with stricter control on sulfur emissions. So far, the Baltic Sea and the North Sea have been designated as SECAs. In these areas, the marine residual fuel sulfur content used on board ships must not exceed 1.5% or ships must have an exhaust gas cleaning system to limit the SO_X emissions.[12]

European Union

The European Commission defines fuel grades in three levels, according to the sulfur content in the fuel. Quality 1 (MGO) has a sulfur limit less than 0.2%, Quality 2 (MDO) has 1.5% sulfur content or less, and Quality 3 (IFO) has a sulfur limit between 1.5 and 4.5%.[13]

Since 2000, marine gas oil has been limited to 0.2% sulfur content in Europe. The European Commission Directive (1999/32/EC) will change the sulfur content limit of distillate fuel intended for marine use in ocean-going vessels to 0.1% as of January 2008. Recent amendments to the Directive will introduce 0.1% sulfur for all marine fuel used at berth commencing in 2010. The Directive also states that "the Community will be advocating more effective protection of areas sensitive to SO_X emissions and a reduction in the normal limit value for bunker fuel oil (from the present 4.5%) at the continuing and future negotiations on the MARPOL Convention within the IMO."[14]

Table 2.2 compares the three European Union (EU) levels for marine diesel fuel to the ISO specifications, where the RM specifications represent the residual marine fuels.

[12] IMO, *http://www.imo.org*.
[13] MARINTEK, *Summary Report - Application of Low Sulphur Marine Fuels*, 2003.
[14] Council Directive 1999/32/EC of 26 April 1999, *Official Journal* L121, pp.0013-0018.

Table 2.2: Summary of European Commission Marine Fuels

Common Name	EU Fuel Level	EU Sulfur, percent	ISO Fuel Grade	ISO Sulfur, percent
MGO	Quality 1	<0.2%	DMA	<1.5%
MDO	Quality 2	<1.5%	DMB/DMC	<2.0%
IFO	Quality 3	1.5 – 4.5%	RMs	<5.0%

United States

Currently, there are no U.S. laws or regulations concerning marine fuel for ocean-going vessels; i.e., those with marine diesel engines with a per-cylinder displacement greater than 30 liters. In the future, the U.S. Environmental Protection Agency (EPA) may consider proposing regulations for these engines, also known as Category 3 engines. EPA is also considering establishing the West Coast or the coastal waters of North America as a SECA to reduce the sulfur content of marine residual fuel used by the ocean-going vessels' main engines to 1.5%.[15]

There are proposed regulations in California that may affect marine fuel used for the auxiliary engines of ocean-going vessels. The ARB has drafted a proposal for auxiliary engines that would require ocean-going vessels to use cleaner fuels in California coastal waters, such as 0.2% sulfur marine distillate fuel by July 2006 and 0.1% sulfur marine distillate fuel by 2010.[16]

2.2.2 Landside Fuel Regulations

Although the standards for onroad and offroad grade No. 2 diesel fuel do not currently meet the SOLAS minimum flashpoint requirement set for fuel oil used in propulsion and auxiliary engines of ships that make trips overseas, they are included in this study because of their low sulfur content, broad availability, and potential for use in marine engines.

Federal

The current federal sulfur limit for onroad diesel fuel is 500 ppm. EPA standards for highway diesel fuel take effect starting in 2006,[17] capping diesel fuel sulfur levels at 15 ppm (ULSD) for all highway vehicles. The phased approach includes highway diesel fuel fully meeting the 15 ppm sulfur content by 2010. Currently, Federal offroad diesel fuel has a sulfur limit up to 5,000 ppm. The offroad diesel fuel standards for

[15] EPA, *Final Regulatory Support Document: Control of Emissions from New Marine Compression-Ignition Engines at or Above 30-Liters per Cylinder*, January 2003, EPA420-R-03-004.
[16] ARB, Public Workshop on Draft Proposal to Reduce Emissions from Ship Auxiliary Engines, 18 May 2005.
[17] 40 *Code of Federal Regulations* (CFR) Parts 69, 80 and 86, *Control of Air Pollution From New Motor Vehicles: Heavy-Duty Engine, Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements*.

locomotive and marine engines less than 30 liters per cylinder may start as early as 2007 with large refiners producing fuel with 500 ppm sulfur content and 15 ppm by 2012.[18]

California

In California, the current sulfur limit for onroad diesel fuel is 500 ppm. The California Diesel Fuel Regulations require onroad diesel fuel sold in California to have a sulfur content of 15 ppm or less by 2006.[19] The standard may be extended for fuel sold for use in locomotive or marine vessels.[20] The proposed regulatory action may take effect as early as January 2006 for fuel sold to harbor craft. Diesel fuel sold or supplied within the South Coast Air Quality Management District (SCAQMD) for use in harbor craft must meet the same applicability requirements as onroad diesel fuel. This regulatory action will not impact ocean-going vessels since it applies only to harbor craft that are registered in the U.S., weigh less than 10,000 gross tons, and are propelled by a marine diesel engine with a per-cylinder displacement of less than 30 liters (Category 1 and 2).

Outside the United States

Examples of countries that have regulations in place to lower the concentration of sulfur for onroad diesel fuel include Canada, Japan, Mexico, and the European Union.

Canadian regulations are aligned with, or becoming aligned with, U.S. requirements. In Canada, the current onroad sulfur limit is 500 milligrams per kilogram (mg/kg, equivalent to ppm), and proposed regulations will lower the limit to 15 ppm in June 2006.[21] Other proposed regulations will provide an initial limit of 500 mg/kg for offroad, rail and marine diesel fuels in June 2007. In June 2010, the final limit will be 15 mg/kg for offroad diesel fuel, and in June 2012, the final limit will be 15 mg/kg for production and imports of rail and marine diesel fuels.[22]

In Mexico, the standard 5,000 ppm sulfur content onroad diesel is gradually being replaced by a lower sulfur grade (500 ppm) onroad diesel.[23]

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[18] EPA, Advanced Notice of Proposed Rulemaking: *Control of Emissions of Air Pollution from New Locomotive Engines and New Marine Compression-Ignition Engines Less Than 30 Liters per Cylinder*, 69 *Federal Regulations* (FR) 39276, 29 June 2004.

[19] 2281 *California Code of Regulations* (CCR) 13.

[20] ARB, Proposed Extension of the California Standards for Motor Vehicle Diesel Fuel to Diesel Fuel Used for Intrastate Diesel-Electric Locomotives and Harbor craft, Resolution 04-38, 18 November 2004.

[21] Environment Canada, Canadian Environmental Protection Act, 1999, "Sulphur in Diesel Fuel Regulations, Regulatory Impact Analysis." See: *http://www.ec.gc.ca/CEPARegistry/regulations/RegText.cfm?intReg=63&intDocument=286*.

[22] Environment Canada, *Reply to Comments on Submissions Received on the August, 2003 Environment Canada Discussion document* "Reducing the Level of Sulphur in Canadian Off-Road Diesel Fuel," October 2004..

[23] *Dieselnet* fuel regulations, *www.dieselnet.com.*

In 2005, the sulfur content of onroad diesel fuel sold in Europe will go down from 35 ppm sulfur content to 5 ppm sulfur content.[24]

In Japan, the maximum acceptable sulfur content for diesel fuel has been set at 500 ppm since 1997.[25] According to the Japan Petroleum Institute, onroad diesel with a sulfur content of 10 ppm has been available since the beginning of 2005.[26]

Table 2.3 below summarizes the landside diesel fuel requirements as discussed in this section with expected year of action. The year may change in some cases, as the regulations have not yet been adopted.

Table 2.3: Summary of Diesel Fuel Requirements by Country

Country	Current Sulfur Limit (ppm)	Future Sulfur Limit (ppm)	Year
Canada			
Onroad	500	15	2006
Offroad	2,400[27]	500/15	2007/2010-2012[28]
European Union	35	5	2005
Japan	500	10	2005
Mexico	5,000	500	gradual
United States			
Onroad	500	15	2006 - 2010
Offroad	5,000	500/15	2007/2012[29]
California (all)	500	15	2006[30]

[24] European Directive 2003/17/EC, March 2003.
[25] Japan Petroleum Energy Center, *Survey of Petroleum Refining Technology for High-quality (Ultra-low Sulfur Content) Diesel Fuel*, 2001.
[26] Communication between Japan Petroleum Institute and Starcrest Consulting Group, LLC, 16 March 2005.
[27] Environment Canada, *Final Report on the Government Working Group on Sulphur in Gasoline and Diesel Fuel Setting a Level for Sulphur in Gasoline and Diesel Fuel*, 14 July 1998. Through a memorandum of understanding between Environment Canada and Canadian refiners, in 1997, the average sulphur level for onroad diesel and regular (offroad) diesel were 300 ppm and 2,400 ppm respectively.
[28] 2012 schedule applies to rail and marine diesel fuel; sales (as opposed to production and importation) of rail and marine diesel fuel would remain subject to the 500 mg/kg limit in order to provide for a sales outlet for fuel that may be contaminated during distribution.
[29] Locomotives and harbor craft only.
[30] Proposed for locomotives and harbor craft; may become effective as early as 2006 for harbor craft.

SECTION 3 PORTS CONSIDERED

According to Mercator,[31] the Ports of Los Angeles and Long Beach have experienced remarkable growth in container handling volume over the last 15 years. This growth has been part of a worldwide increase in container trade. Between 1990 and 2003, container volumes carried on the Transpacific (Asia-North America), Transatlantic (Europe-North America) and Asia-Europe routes has nearly tripled. Lower sulfur fuel availability was evaluated for the Ports of Los Angeles and Long Beach, the ports of origination and call for China Shipping container vessels calling at Berth 100, and for the top twenty ports of origination and call by frequency, beyond those serving China Shipping.

In order to define the ports, countries and regions to be studied, Mercator Transport Group prepared a list of ports of origination or call for containerships with service to the Port of Los Angeles. For vessels that call on Berth 100 (for China Shipping), five ports were identified. An additional 22 ports for ships calling on the Port of Los Angeles are listed as ranked. Although the scope required inclusion of only the top 20 ports, after those calling on the China Shipping Berth 100 terminal, an additional two were included because the 19th through 22nd ranked ports had the same number of calls. The Ports of Rotterdam (the Netherlands) and Le Havre (France) were also included to obtain a representation of European ports, which would otherwise have been excluded from the study. Including the Ports of Los Angeles and Long Beach, a total of 31 ports were considered, as shown in Table 3.1 and Figure 3.1.

For the China Shipping and top twenty (top twenty-two) ports studied, the country of China dominated, with 28% of the vessel calls, followed closely by the U.S. with 26%, and Japan with 17%, as shown in Figure 3.2. When comparing calls regionally, two-thirds of the vessels serving the Port of Los Angeles made calls at ports in Asia, and one-third in the U.S., as shown in Figure 3.3. The calls on U.S. ports are typically *en route* calls; only U.S. Flag carriers may carry cargo between U.S. ports (under the Jones Act). There were a total of 345 calls on the ports of origination/call for vessels serving the Port of Los Angeles in 2004; under the scope of this study, ports accounting for 239 (244 including those in Europe) of those calls were included, representing 70% of the total.

The ports considered in this study include the largest in the world, in order based on 2004 tonnage:[32]

(1) Singapore,
(2) Shanghai, and
(3) Rotterdam.

[31] Mercator Transport Group, *Forecast of Container Vessel Specifications and Activities Within San Pedro Bay*, 22 February 2005.
[32] *China Daily* 2005. ChinaDaily.com, *Shanghai becomes world's second-largest port*, 17 May 2005.

Table 3.1: Ports Considered

Port of Call/Origination	Country	Calls By Ships Serving the Port of Los Angeles
San Pedro Bay Ports		
Los Angeles	USA	Not applicable
Long Beach	USA	Not applicable
Ports for Vessels Calling on China Shipping Berth 100		
Hong Kong	China	25
Busan	South Korea	14
Yantian	China	11
Shanghai	China	12
Xiamen	China	5
Ports for Vessels Calling on the Port of Los Angeles, Other than China Shipping Berth 100		
Oakland	USA	26
Kaohsiung	Taiwan	18
Yokohama	Japan	13
Kobe	Japan	12
Charleston	USA	8
Nagoya	Japan	8
Ningbo	China	8
New York/New Jersey	USA	8
Tokyo	Japan	8
Manzanillo	Panama	6
Seattle	USA	6
Singapore	Singapore	6
Balboa	Panama	5
Chiwan	China	5
Kwangyang	South Korea	5
Norfolk	USA	5
Vancouver	Canada	5
Honolulu	USA	4
Lazaro Cardenas	Mexico	4
Tanjung Pelepas	Malaysia	4
Qingdao	China	4
Savannah	USA	4
European Ports		
Rotterdam	The Netherlands	3
Le Havre	France	2

Figure 3.1: Ports Considered by Region

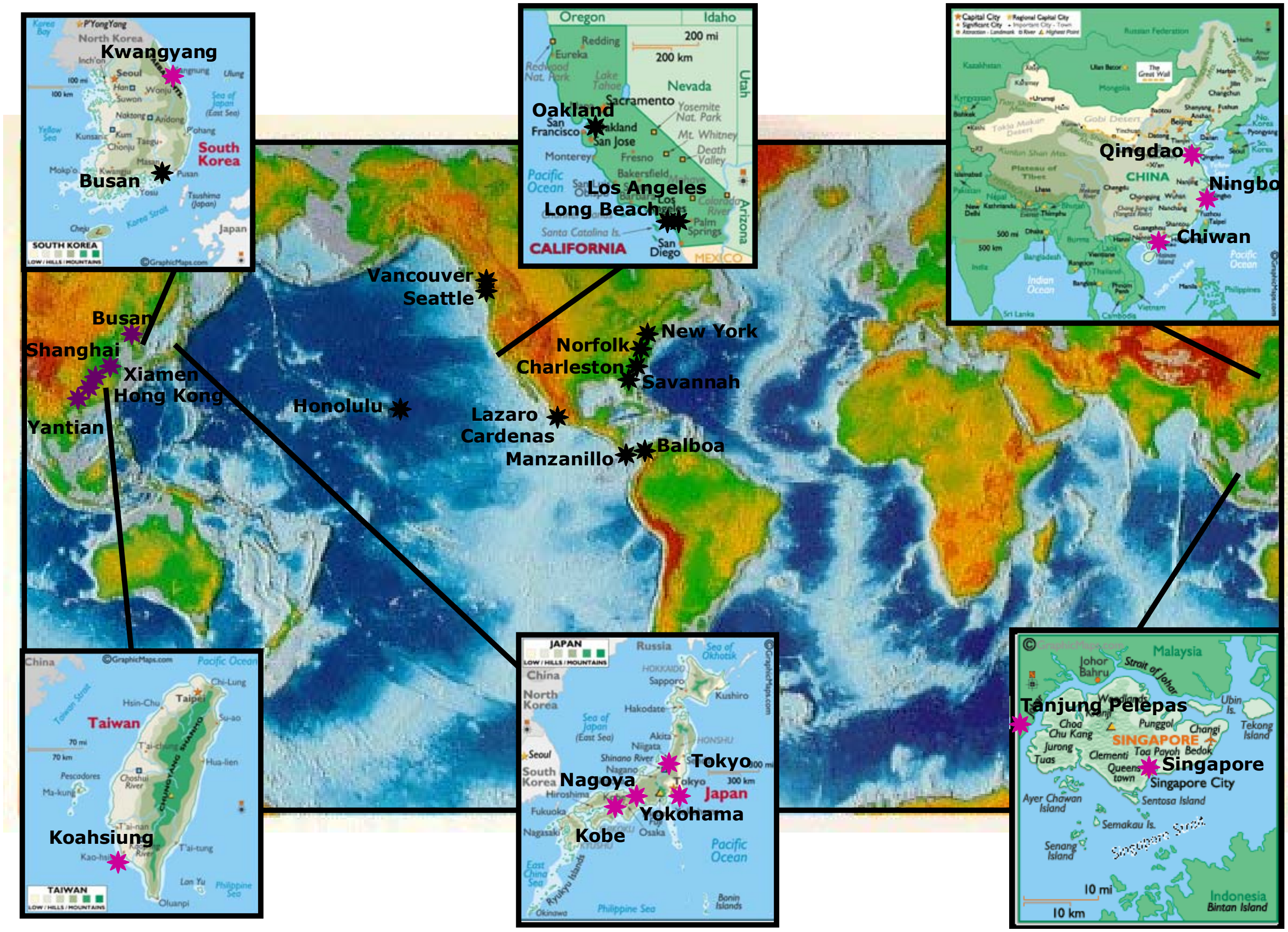


Figure 3.2: Ports by Country

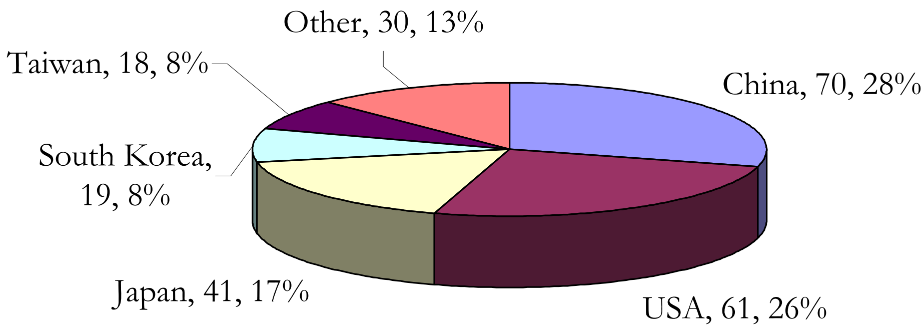
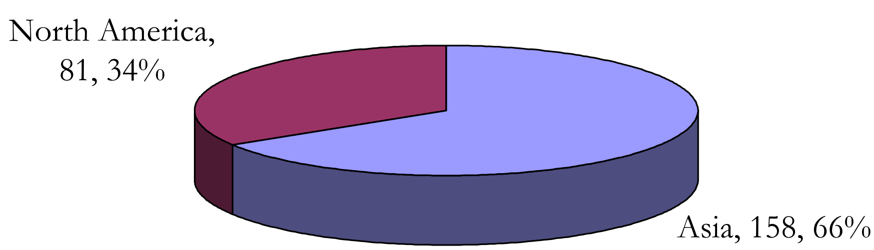


Figure 3.3: Ports by Region



The geographic distribution of port calls en route to the Port of Los Angeles (LA) is presented in Figure 3.4. The predominant distribution involves direct service from Asia (Transpacific) (68%), followed by services from the East Coast of North America (17%), typically as part of an extended service that also includes ports in Asia or Europe, and finally Transpacific services that call Los Angeles after first calling other West Coast North America ports, including Oakland (11%) and Vancouver/Seattle (4%). For purposes of this illustration, Honolulu was included with the Transpacific route, and Panama (for the Panama Canal) and Mexico were included in the East Coast route.

The top ports by frequency of service to the Port of Los Angeles (those with double-digit numbers of calls) were:

- Oakland, California, U.S.
- Hong Kong, China
- Kaohsiung, Taiwan
- Busan, South Korea
- Yokohama, Japan
- Kobe, Japan
- Shanghai, China
- Yantian, China

Mercator discusses these ports in their Vessel Forecast Study, earlier cited. All except Oakland were identified as key San Pedro Bay (i.e., Ports of Los Angeles and Long Beach) trading ports. Hong Kong is the world's largest container port in terms of annual through-put and has seven separately operated marine terminals, with a total of 24 berths. An additional terminal is under consideration. Kaohsiung is Taiwan's leading port, although the more rapid expansion of China's liner traffic and container ports has resulted in fewer shipping lines using Kaohsiung as their primary hub port in Asia. Kaohsiung has 22 separate terminals. Busan has nine separately-operated container terminals with a total of 20 berths.

The Ports of Tokyo and Yokohama serve Japan's largest metropolitan area. Yokohama has three locations with a total of seven berths. Tokyo has three dedicated container terminals with a total of 10 berths. Kobe is one of two leading ports (along with Osaka) for West Japan. Fourteen berths (seven on each of two man-made islands) are used for cargo handling. The Port of Shanghai, located near the mouth of the Yangtze River, surpassed the Port of Rotterdam as the second largest port in the world (after Singapore) in 2004.[33] Yantian is South China's leading container port. Once the next phase of expansion is completed in 2006, they will have nine berths. The Port of Oakland is the fourth largest container port in the U.S.

[33] *China Daily* 2005.

Figure 3.4: Distribution of Port Calls