Office of Transportation and Air Quality
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Port Operational Strategies: Vessel Speed Reduction

This fact sheet is one of a series of documents produced by the EPA Ports Initiative to inform port stakeholders about potential emission reduction strategies.[1] Each fact sheet contains basic information about the strategy, emission impacts, cost components, and example programs. While each strategy can achieve benefits on its own, implementing them together could create synergies.[2]

Strategy Summary

Description: Vessel speed reduction (VSR) consists of establishing a zone around a port within which vessels operate at or below a defined speed—typically less than normal cruise speed. This reduces propulsion engine emissions and fuel consumption, decreasing pollution in and around the port. Ports such as Los Angeles, San Diego (Figure 1), and New York/New Jersey have established VSR zones ranging from 20 to 40 nautical miles, with typical speed limits between 10 and 15 knots.

Figure 1. Port of San Diego VSR Zone[3]

Emission reductions from VSR programs depend on the size of the zone, vessel type, and vessel speed. As one example, emissions savings from vessels traveling at 12 knots within 24 nautical miles from the Port of Los Angeles were estimated to be 37 percent for CO_2 and NO_x and 49 percent for diesel PM and SO_2.[4]

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1 The emissions evaluated in these fact sheets include nitrogen oxides (NO_x), particulate matter (PM), hydrocarbons (HC), carbon monoxide (CO), carbon dioxide (CO_2), and sulfur dioxide (SO_2).

2 See the EPA Ports Initiative's fact sheets on virtual vessel arrival (https://www.epa.gov/ports-initiative/virtual-vessel-arrival-systems-ports-improves-air-quality-and-saves-fuel), port management information systems (https://www.epa.gov/ports-initiative/management-information-systems-improve-operational-efficiencies-and-air-quality), and gate management (https://www.epa.gov/ports-initiative/port-gate-management-strategies-improve-air-quality-and-efficiency-ports).

3 Port of San Diego. 2020. Vessel Speed Reduction Map. https://www.portofsandiego.org/media/241. Accessed 3-5-2021.

4 California Air Resources Board. 2007. Vessel Speed Reduction for Ocean-Going Vessels Workshop. https://www.arb.ca.gov/ports/marinevess/vsr/docs/pres07122007.pdf. Accessed 3-5-2021.

Advantages: Reducing vessel speeds decreases fuel usage and engine emissions near port areas, which can improve the health of port workers and nearby communities.[5] Vessels such as container ships, cruise ships, and roll-on/roll-off vessels, which have typical operating speeds above 20 knots, achieve larger fuel and emission benefits than smaller, slower-moving vessels such as bulkers, general cargo ships, and tankers. For example, a container ship with a typical cruising speed of 21 knots reducing its speed by 20 percent to 16.8 knots may reduce engine load by up to 50 percent, with corresponding reductions in fuel consumption, NO_x, and PM emissions. Meanwhile, a tanker slowing from 18 to 16.8 knots may reduce fuel consumption and emissions by the still significant amount of 20 percent.

Figure 2 illustrates an often-cited relationship between vessel speed and potential benefits, based on the Propeller Law curve.[6]

While slowing down vessels near ports will increase their transit time, the increase may not be significant for most. For example, one study estimated that slowing from 20 to 12 knots (i.e., by 40 percent) in a 20-nautical-mile VSR zone would cut fuel consumption and emissions by 70–75 percent[8] while adding only about 45 minutes to travel time. A 45-minute delay is generally within the typical arrival window of two hours.

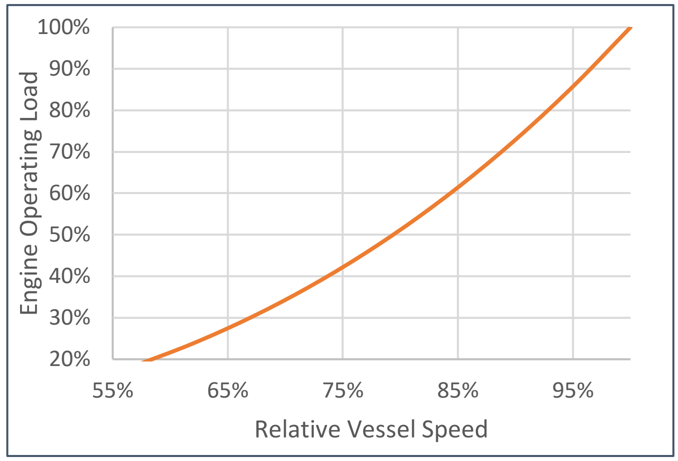

Figure 2. Engine Load vs. Vessel Speed[7]

Considerations: Estimating how a VSR zone could affect a specific port requires compiling data on the number and types of vessels that visit the port, including their speed within the zone. This is typically done using Automatic Identification Systems (AIS) data. Vessels that use AIS transmit a signal every few seconds, identifying their locations and speeds. AIS data are time specific and change from year to year.

Speeds can be verified using ground-based AIS out to approximately 40 miles from shore. Satellite-based AIS effectively provides global coverage and can be used where terrestrial systems are not available, allowing VSR zones to be adopted and monitored at virtually any port.

Appropriate port size and type: This strategy can be used for ports of any size and type, though larger ports that service higher-speed vessels would see the largest reduction in fuel consumption and emissions within the VSR zone.

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5 Exposure to air pollution associated with emissions from diesel engines can contribute to significant health problems—including premature mortality, increased hospital admissions for heart and lung disease, increased cancer risk, and increased respiratory symptoms—especially for children, the elderly, outdoor workers, and other sensitive populations. (See U.S. Environmental Protection Agency. 2014. Near Roadway Air Pollution and Health: Frequently Asked Questions. https://nepis.epa.gov/Exe/ZyPDF.cgi/P100NFFD.PDF?Dockey=P100NFFD.PDF. Accessed 3-5-2021).

6 U.S. Environmental Protection Agency. 2020. Ports Emissions Inventory Guidance: Methodologies for Estimating Port-Related and Goods Movement Mobile Source Emissions. https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P10102U0.pdf. Accessed 3-5-2021.

7 Developed using the Propeller Law curve, assuming a vessel maximum design speed of 21 knots.

8 Bialystocki, N., and D. Konovessis. 2016. On the Estimate of Ship's Fuel Consumption and Speed Curve: A Statistical Approach. Journal of Ocean Engineering and Science 1(2): 157–166. http://joes.sjtu.edu.cn/ueditor/net/upload/2016-05-24/c4870989-3cb5-49e3-939f-278003e04a02.pdf. Accessed 3-5-2021.

Furthermore, larger ports are likely to have professional staff who would be better able to monitor participation. Constraints such as safety and navigation may prohibit full use of vessel speed reduction.

Emission Reductions[9]

Primary Pollutants affected: NO_x, PM, HC, CO, CO_2, and SO_2

Anticipated reductions: Reductions will vary depending on the characteristics of the fleet that visit the port: vessel type, engine tier level, design speed, and typical operating speed. Nitrogen oxides (NO_x) reductions of up to 45 percent were reported in one study.[10] The VSR program operated by the Port of Long Beach was estimated to reduce NO_x emissions by 747 tons and CO_{2e} emissions by 28,600 tons in 2008, based on 2,477 vessel entrances per year.[11]

Calculation methodology: The data inputs required to calculate VSR program emission reductions, and potential sources of these data, are listed below.

- Size and location of slow steaming zone (nautical miles), determined by port policy.
- *Actual operating speed of vessels approaching port (knots),* determined using AIS data for the VSR area. (Alternatively, information can be obtained from the Marine Exchange and ship records.)
- Target slow steaming speed (knots), determined by port policy.
- *Fuel type,* determined by assuming 1,000 ppm distillate/residual fuel mix for ocean-going vessels based on U.S. Emission Control Area zone requirements.
- *Propulsion engine tier level and category,* obtained from the participating vessels or classification society vessel attribute data. (Most large vessel engines will be slow-speed, Tier 0, Category 3, but newer vessels with higher-tier engines should also be accounted for as appropriate.)
- *Propulsion engine power (kW),* obtained from participating vessels, classification society vessel attribute data, or defaults from EPA's Port Emissions Inventory Guidance.[12]
- *Maximum design speed of vessels visiting the port (knots),* obtained from participating vessels or from classification society vessel attribute data. Anticipated cruising speed is assumed to be 0.94 times the vessel's design speed (from EPA's Port Emissions Inventory Guidance).
- *EPA emission factors (g/kWh),* based on EPA's Port Emission Inventory Guidance.

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9 The information in this section is for illustration: although the types of inputs and methods used in this section are generally consistent with EPA established methodologies, it does not constitute official EPA technical guidance for regulatory purposes. Please note that EPA has comprehensive guidance on developing inventories of emissions from ports and port-related goods movement. EPA's *Port Emissions Inventory Guidance*, September 2020, EPA-420-B-20-046, is available at EPA's web site at: www.epa.gov/state-and-local-transportation/port-emissions-inventory-guidance. Accessed 3-5-2021.

10 Boersma, K.F., G.C.M Vinken, and J. Tournadre. 2015. Ships Going Slow in Reducing Their NO_x Emissions: Changes in 2005–2012 Ship Exhaust Inferred from Satellite Measurements over Europe. Environmental Research Letters 10(7). https://pure.tue.nl/ws/files/22832393/BoersmaShipsgoing2015.pdf. Accessed 3-5-2021.

11 OECD/International Transport Forum. 2018. Reducing Shipping Greenhouse Gas Emissions: Lessons from Port-Based Incentives. https://www.itf-oecd.org/sites/default/files/docs/reducing-shipping-greenhouse-gas-emissions.pdf. Accessed 3-5-2021.

12 U.S. Environmental Protection Agency. 2020. Ports Emissions Inventory Guidance: Methodologies for Estimating Port-Related and Goods Movement Mobile Source Emissions. https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P10102U0.pdf. Accessed 3-5-2021.

- *Slow speed adjustment for each pollutant,* based on EPA's Port Emission Inventory Guidance (for cases where the speed limit requires a vessel to operate below 20 percent engine load).

Use the following equation to calculate emission reductions for a vessel whose original operating speed is above the VSR program speed:

$$ER_i = \Bigg[\bigg(\left(\frac{SP_1}{MaxSP}\right)^3 \times \frac{SEG}{SP_1} \times SSA_1 - \left(\frac{SP_N}{MaxSP}\right)^3 \times \frac{SEG}{SP_N} \times SSA_N\bigg) \times VP \times EF + \left(\frac{SEG}{(SP_N - SP_1)}\right) \times \big((AP \times LF \times EF_{ai}) + (BP \times EF_{bi})\big)\Bigg] \times C$$

Where:

ER_i = Emission reduction for pollutant i (tons)

SP_1 = Speed prior to entering restricted zone (knots)

SP_N = Maximum speed within restricted zone (knots)

$MaxSP$ = Maximum design speed for vessel (knots)

VP = Vessel power (kW) for vessel

AP = Auxiliary power (kW)

LF = Auxiliary operating load factor (unitless)

BP = Boiler power (kW)

SEG = Length of transit segment (NM)

EF_i = Propulsion emission factor for pollutant i (g/kWh), by vessel engine category, engine tier, and fuel type, available from EPA's *Ports Emissions Inventory Guidance: Methodologies for Estimating Port-Related and Goods Movement Mobile Source Emissions* document

EF_{ai} = Auxiliary emission factor for pollutant i (g/kWh), by vessel engine category, engine tier, and fuel type, available from EPA's *Ports Emissions Inventory Guidance: Methodologies for Estimating Port-Related and Goods Movement Mobile Source Emissions* document

EF_{bi} = Boiler emission factor for pollutant i (g/kWh), by fuel type, available from the EPA's *Ports Emissions Inventory Guidance: Methodologies for Estimating Port-Related and Goods Movement Mobile Source Emissions* document

SSA_1 = Slow speed adjustment if $\left(\frac{SP_1}{MaxSP}\right)^3$ is less than 0.2 (EPA's Port Emission Inventory Guidance document provides slow speed adjustment factors); otherwise SSA_1 is set to 1

SSA_N = Slow speed adjustment if $\left(\frac{SP_N}{MaxSP}\right)^3$ is less than 0.2; otherwise SSA_N is set to 1

C = Grams/ton conversion factor (1.10231×10^{-6})

If the auxiliary engine power (AP in kW) and operating load factors (LF) are unknown, a user may employ default values for effective load (AP x LF) by ship type, available from the *U.S. EPA Ports Emissions Inventory Guidance: Methodologies for Estimating Port-Related and Goods Movement Mobile Source Emissions document's Appendix, Table E1.*[13]

[13] U.S. Environmental Protection Agency. 2020. Ports Emissions Inventory Guidance: Methodologies for Estimating Port-Related and Goods Movement Mobile Source Emissions. https://www.epa.gov/ports-initiative/port-and-goods-movement-emission-inventories. Appendix Table E-1. Accessed 3-5-2021.

If the boiler power rating factor is unknown, a user may employ default power values (BP in kW) by ship type, from the *U.S. EPA Ports Emissions Inventory Guidance: Methodologies for Estimating Port-Related and Goods Movement Mobile Source Emissions document's Appendix, Table E2.*[14]

Except for cruise ships, auxiliary power and boiler impacts are minimal on emission reductions allowing users to simplify the equation if desired, as shown in the following example.

Example calculation: A tanker has a propulsion engine of 9,000 kW and a maximum design speed of 18 knots. It reduces its speed from 15 to 12 knots as it enters the speed reduction zone. Assume a 10 nautical mile waterway segment. The propulsion engine load at the reduced speed is 29.6 percent, so a low load adjustment is not needed. The pollutant being calculated in this example is CO_2, and the emission factor for this engine was identified to be 589 g CO_2/kWh.

$$ER_{CO2} = \left(\left(\frac{SP_1}{MaxSP}\right)^3 \times \frac{SEG}{SP_1} - \left(\frac{SP_N}{MaxSP}\right)^3 \times \frac{SEG}{SP_N}\right) \times VP \times EF \times C$$

$$ER_{CO2} = \left(\left(\frac{15\ NM/hr}{18\ NM/hr}\right)^3 \times \frac{10\ NM}{15\ NM/hr} - \left(\frac{12\ NM/hr}{18\ NM/hr}\right)^3 \times \frac{10\ NM}{12\ NM/hr}\right) \times 9{,}000\ kW \times 589\ \frac{g\ CO_2}{kWh} \times 1.10231 \times 10^{-6}$$

ER_{CO2} = 0.8 tons of CO_2

This calculation should be completed for each vessel operating above the proposed speed limit, for all segments included in the port's VSR area.

Cost Components[15]

Capital costs: Additional capital investment will likely be limited to:

- Purchase of vessel monitoring software to help compile real-time AIS data (may be included as part of a renewable AIS subscription)

Capital costs should be annualized over the expected life of the software to estimate annual program costs.

Operational costs: Day-to-day operational costs may include:

- Labor for system administration (including communications, recordkeeping, and in-house monitoring of AIS data)
- Fees to external parties to monitor vessel traffic (e.g., fees to one of the 13 local marine exchanges[16] in the United States), in lieu of in-house monitoring of AIS data
- Fees for third parties to provide vessel and engine data for participating ships (e.g., annual subscription fees to classification societies)
- Labor and other nominal operating costs from increased vessel transit times (if any)

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[14] U.S. Environmental Protection Agency. 2020. Ports Emissions Inventory Guidance: Methodologies for Estimating Port-Related and Goods Movement Mobile Source Emissions. https://www.epa.gov/ports-initiative/port-and-goods-movement-emission-inventories. Appendix Table E-2. Accessed 3-5-2021.

[15] The information in this section is for illustration: it does not constitute official EPA technical guidance for regulatory assessments.

[16] Marine exchanges are local organizations that monitor ship movements, often in partnership with the U.S. Coast Guard Vessel Traffic Service. These organizations can help identify vessels and evaluate their speeds.

- Port operators may also incur costs from providing incentives to vessel operators to encourage participation (see "Example Programs" below). These costs would amount to savings for vessel operators (e.g., dockage fee discounts).

Cost savings: Costs savings may be realized from:

- Reduced fuel consumption near the port due to slower speeds

Example Programs[17]

The Port of Los Angeles launched its VSR program in 2001 and has seen steady increases in program participation over time. Participation incentives include dockage fee discounts for vessel operators with 90 percent or greater compliance for the calendar year. Between 2008 and 2019, the Port paid out $19.9 million in incentives to VSR program participants. Participation also qualifies operators for a VSR recognition award to recognize their environmental contributions.

Attainment of speed targets is measured by the Marine Exchange of Southern California, based on weighted average speeds measured over trip segments 5 nautical miles in length.[18] In 2019, the Port achieved a 91 percent participation rate within 20 nautical miles and an 87 percent participation rate within 40 nautical miles. Selected operator participation rates are shown in Figure 3 (on the next page) along with incentive thresholds, based on data for 2019.

Other programs include:

- The Port Authority of New York and New Jersey offers incentives for ocean-going vessel operators to comply with its VSR by giving additional points to its Clean Vessel Incentive score. The Clean Vessel Incentive Program rewards operators that reduce vessel emissions through voluntary engine, fuel, and technology enhancements; points are also awarded for exceeding current international emission standards based on established metrics such as Environmental Ship Index scores. Accumulated points can be applied to financial incentives managed by the Port Authority. Based on the 2018 port emissions inventory, VSR accounted for a reduction of 598.5 tons of NO_x, 7.1 tons of PM, and 15,626 tons of CO_{2e}.[19]
- The Port of Long Beach provides a 25 percent reduction in dockage fees for fleets with a 90 percent participation rate within 40 nautical miles of Point Fermin, and a 15 percent reduction for participation within 20 nautical miles. The Port achieved 95 percent participation within the 20-mile zone and almost 90 percent within the 40-mile zone, which the port estimates resulted in the reduction of 28 tons of diesel particulate matter, 1,311 tons of NO_x, 38 tons of sulfur oxides and 58,964 tons of CO_{2e} in 2017.[20]

[17] Emission reductions and cost-effectiveness can vary substantially from port to port depending on fuel type, vessel mix, program compliance rates and other factors. Accordingly, care should be taken when comparing program benefits and cost across different programs.

[18] Port of Los Angeles. n.d. Vessel Speed Reduction Incentive Program Guidelines. https://www.portoflosangeles.org/environment/air-quality/vessel-speed-reduction-program. Accessed 3-5-2021.

[19] Port Authority of New York and New Jersey. Clean Vessel Incentive Program. https://www.panynj.gov/port/en/our-port/sustainability/clean-vessel-incentive-program.html. Accessed 3-5-2021.

[20] Renee Moilanen, Manager of Air Quality Practices Port of Long Beach. Email communication, 11-19-2018.

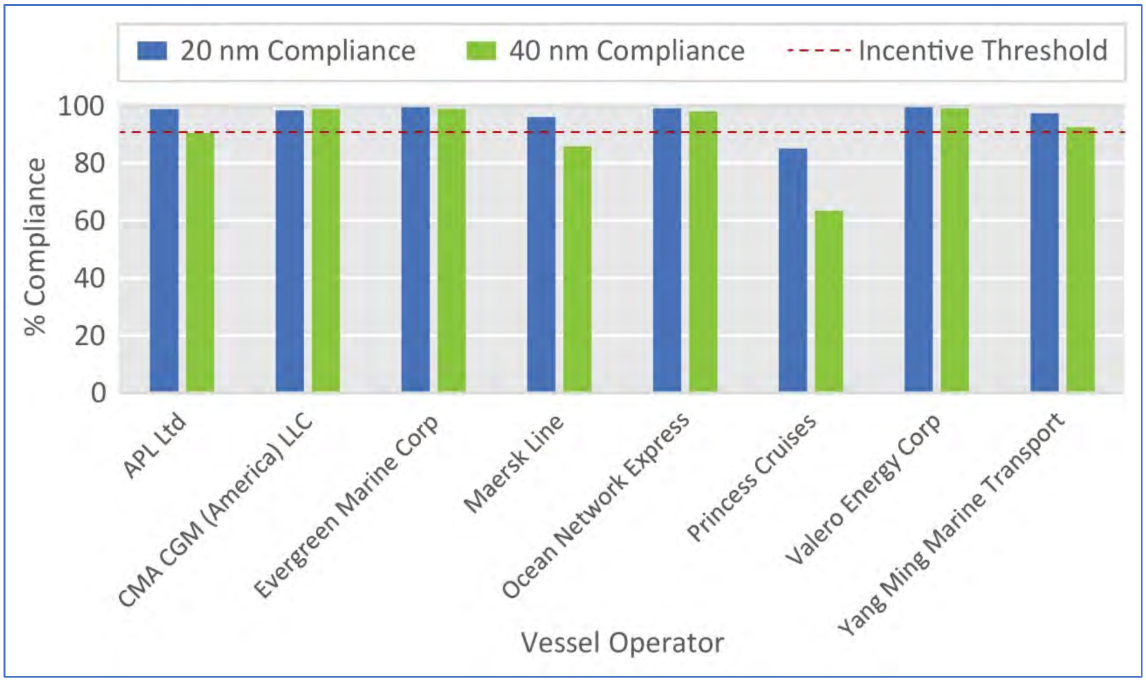

Figure 3. Selected VSR Operator Participation, Port of Los Angeles (2019)[21]

- San Diego asks cargo vessel operators entering or leaving San Diego Bay to observe a 12-knot speed limit. Cruise ships are requested to observe a 15-knot speed limit. The VSR extends 20 nautical miles.[22] Based on the 2016 port emissions inventory, VSR accounted for a reduction of 62 tons of NO_x and 2,670 tons of CO_{2e}.[23]

Table 1 summarizes key VSR program elements for selected U.S. ports.

Table 1. VSR Program Summary for U.S. Ports[24]

Port	Speed Limit	Zone Size	Fee Discount/Incentive
Los Angeles	12 knots	20–40 nm	15%–30%
Long Beach	12 knots	20–40 nm	15%–25%
San Diego	12 knots	20 nm	Public recognition
New York/New Jersey	10 knots[25]	20 nm[26]	Additional incentive points

[21] Port of Los Angeles Vessel Speed Reduction Program Operator Summary Report, 2019. https://kentico.portoflosangeles.org/getmedia/f899bdf1-4e15-419e-8ec3-2d024c6f75f1/2019_VSR_Counts_POLA. Accessed 3-5-2021.

[22] Port of San Diego. n.d. Maritime-Environment. https://www.portofsandiego.org/environment/energy-sustainability/maritime-environment. Accessed 3-5-2021.

[23] Port of San Diego 2016 Maritime Air Emissions Inventory. ICF, June 2018. https://pantheonstorage.blob.core.windows.net/environment/2016-Maritime-Air-Emissions-Inventory.pdf. Accessed 3-5-2021.

[24] OECD/International Transport Forum. 2018. Reducing Shipping Greenhouse Gas Emissions: Lessons from Port-Based Incentives. https://www.itf-oecd.org/sites/default/files/docs/reducing-shipping-greenhouse-gas-emissions.pdf. Accessed 3-5-2021.

[25] Port Authority of New York and New Jersey. 2018. Clean Vessel Incentive Program. http://www.panynj.gov/about/clean-vessel-incentive-program.html. Accessed 3-5-2021.

[26] 20 nm outside the Territorial Sea Line.