

RESEARCH ARTICLE



On-Site Emission Inventory for Port Areas Along Soai Rap Navigation Channel, Vietnam

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Article History

Received

15 September 2025

Revised 16 March 2026

Accepted 5 April 2026

Keywords

anchorage emissions, greenport adoption, on-site emission inventory, Soai Rap channel





ABSTRACT

The Soai Rap navigation channel in southern Vietnam, spanning 66.6 km and hosting 12 ports and 15 mooring buoys, is undergoing expansion to support regional socioeconomic development. This study aimed to quantify the on-site CO₂ emissions from maritime and port activities along the channel. A combination of bottom-up and top-down emission inventory approaches was applied, focusing on ships (anchoring and maneuvering) and cargo handling equipment, with spatial analysis conducted using QGIS. The results show that ships are the dominant emission source, contributing 1.116 million tons of CO₂, compared with 4.344 thousand tons from cargo handling equipment, out of a total of 1.12 million tons. Bo Bang anchorage accounted for most of the emissions (89.82%), followed by Tan Cang Hiep Phuoc Port (5.85%). Scenario analysis indicates that introducing shore power could reduce emissions by 35.09–99.79%, whereas the electrification of cargo handling equipment could reduce emissions by 0.53–64.53%. Combining both measures yields reductions of 93.03–99.79%. These findings provide evidence for green port development strategies and local air quality improvements. This study highlights the urgent need to expand berth capacity and implement electrification measures and management policies to effectively mitigate port-related emissions.

Introduction

The Soai Rap navigation channel has been established since 2014 to facilitate the relocation of the existing port system from the Saigon River and mitigate traffic load on the Sai Gon - Vung Tau navigation channel. The system of ports, buoy berths, and anchorage areas along the river is currently being invested in and continuously expanded to meet the cargo handling demands in the area, as well as to provide anchorage, waiting, and transshipment support for major ports along the main Sai Gon - Vung Tau navigation channel. Spanning 66.6 kilometers, the Soai Rap channel connects Ho Chi Minh City with neighboring provinces and has become an increasingly important waterway for regional maritime trade in Southeast Vietnam. It accommodates diverse port facilities, including container, bulk, and liquid cargo terminals, and is projected to handle over 60 million tons of cargo by 2030 [1].

In recent years, major investments have focused on upgrading berths and expanding port capacity to meet the socio-economic growth of Southern Vietnam. However, the associated increase in maritime traffic raises concerns about air emissions and their impact on the surrounding urban and coastal environments. Pham et al. [2], researched maritime emissions in Vietnam, have so far concentrated on major port complexes in 2025. The study consistently showed that ship activities dominate port-related emissions, both on-site and

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underway. However, little is known about secondary but fast-expanding navigation channels such as Soai Rap, where anchorage areas play a critical role for ships awaiting berths.

Internationally, a growing body of literature has developed detailed emission inventories using automatic identification system (AIS) data, a bottom-up approach [3], and QGIS-based spatial analysis [4]. While these studies provide valuable insights, they predominantly examine large-scale transit seaports, with limited attention paid to secondary port systems. In Vietnam, the project “Support for Planning and Implementation of Nationally Appropriate Mitigation Actions (SPI-NAMA),” implemented by the Japan International Cooperation Agency (JICA), conducted a greenhouse gas emission inventory in 2020 for several voluntarily participating ports in Ho Chi Minh City using the top-down approach [5]. Addressing this gap, the present study conducted the first comprehensive on-site emission inventory for the Soai Rap navigation channel by explicitly incorporating the anchorage area serving waiting ships. A bottom-up approach was employed to quantify CO₂ emissions from both ships (maneuvering and hoteling) and cargo handling equipment, complemented by spatial analysis in QGIS. Beyond quantification, this study explored the mitigation potential of shore power and electrified equipment by linking emission inventories with feasible green port measures. The novelty of this work lies not in the methodology applied, but in demonstrating how spatially explicit emission mapping of a secondary navigation channel can inform local air quality management to meet international and national legislation requirements for sustainable seaport planning.

Materials and Methods

Study Area

The study area covers port infrastructure along the Soai Rap navigation channel in the Southeast Vietnam seaport, which consists of 12 ports, 15 mooring buoys, and an area for ship anchorage and transshipment of up to 50,000 deadweight tonnage. Accordingly, Soai Rap port areas play the role of a dry port/satellite terminal for Sai Gon - Vung Tau port areas [6]. The 12 ports in the Soai Rap port area are classified by function into six cement ports, three container/general cargo ports, and three specialized ports for handling liquid cargo and Ron-on-Ron-off vessels. The Soai Rap navigation channel is 66.6 km, starting from 10°40'20.5"N 106°46'33.4"E and ending at 10°18'19.50"N 106°58'20.52"E. Ocean-going vessels operating in the port areas of Ho Chi Minh City, Tay Ninh Province, and Dong Thap Province along the Soai Rap channel in 2022 are illustrated in Figure 1 and 2.

Based on the criteria of population size and infrastructure development (from high to low) of the areas along the channel route, Ho Chi Minh City is classified as a special-class urban area, Dong Thap as class I, and Dong Tay Ninh as class II [7]. The Soai Rap channel was established to facilitate the relocation of existing ports from the Saigon River and to relieve congestion on other channels. The cargo volume passing through the port cluster on the Soai Rap navigation channel is quite large. In 2022, there were 1,914 ocean-going vessels that transported approximately 7 million tons of cargo, compared to the projected volume in the master plan for 2030, which ranges from 63.17 to 71.81 million tons. The forecast data reflects the expectations and efforts being made to develop seaports in the area.



Figure 1. The study area covers the port infrastructure along the Soai Rap navigation channel in Southeast Vietnam. The blue color represents the Sai Gon - Vung Tau channel, which is 80.4 km long, while the yellow color represents the Soai Rap channel, which is 66.6 km long and has been officially announced since 2014.

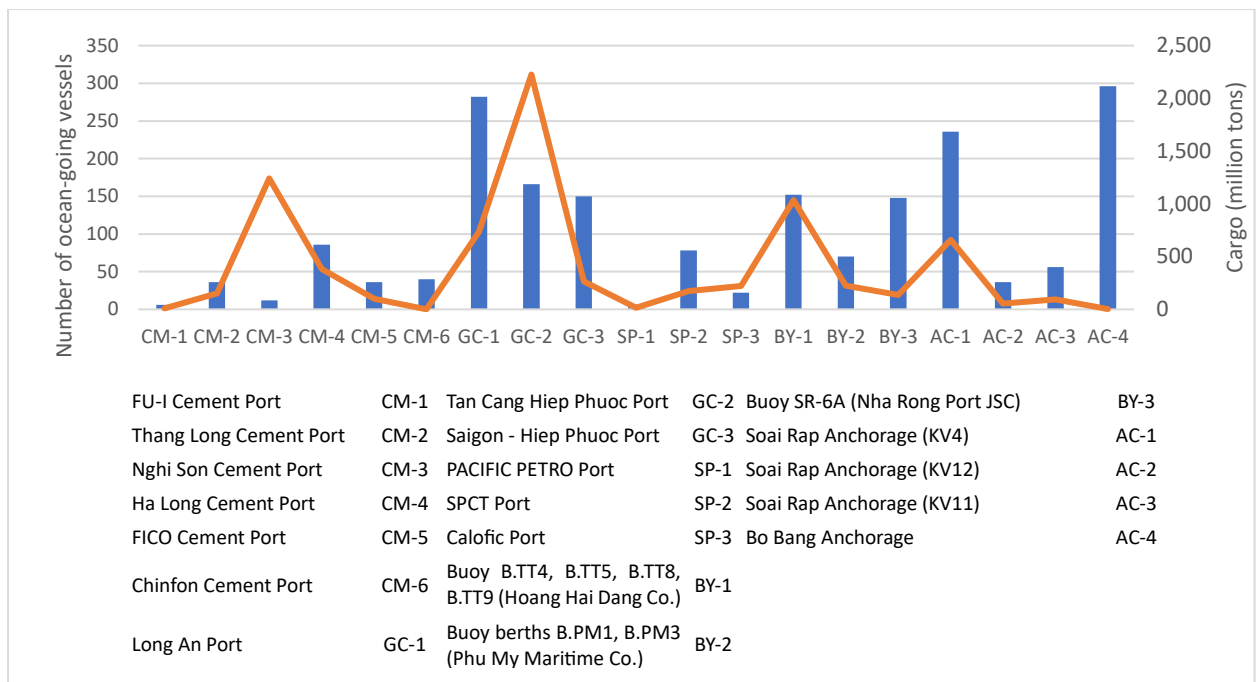


Figure 2. Number of ocean-going vessels and cargo through the Soai Rap port areas. The bar chart represents the number of vessels arriving at and departing from piers, buoy berths, and anchorage areas, while the orange line represents the cargo throughput in 2022.

To support the on-site emission inventory and emission allocation at the seaport along the Soai Rap navigation channel, detailed information was gathered from port enterprises, vessel traffic system (VTS), and maritime administration of Ho Chi Minh City. An on-site emission inventory was conducted, focusing on two main sources: cargo handling equipment and oceangoing vessels operating at seaports along the Soai Rap channel. The results present the spatial distribution of emissions across port areas using QGIS software. This comprehensive data collection ensured a robust and accurate assessment of emission sources and their distribution within the study area, as illustrated in Figure 3.

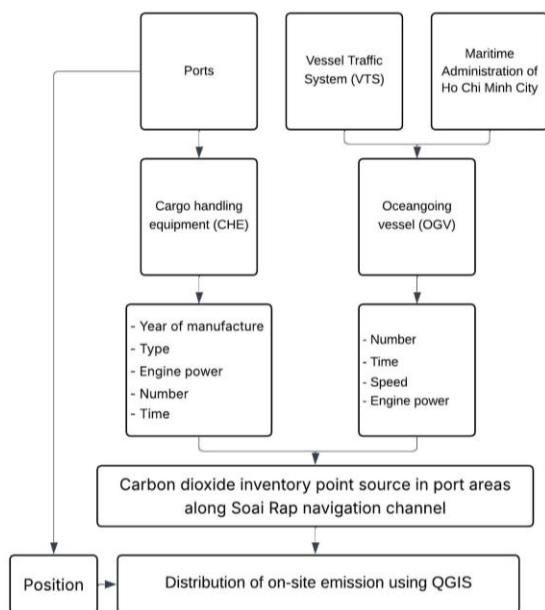


Figure 3. Research process for distribution of on-site emissions in the Soai Rap navigation channel. The emission inventory subjects include cargo handling equipment (collected from port enterprises) and oceangoing vessels (collected from the Maritime Administration of Ho Chi Minh City) operating on the Soai Rap channel in 2022. The result is the spatial distribution of point-source emissions by location and magnitude using QGIS.

Emission Inventory

The emissions inventory methods applied in this study are based on two main approaches for ships: the top-down method, which uses fuel consumption data reported by ship owners/operators, and the bottom-up method (also known as “activity based”), which uses vessel technical specifications combined with operational data [8]. According to Kwon et al. [9], the bottom-up method provides higher accuracy. In recent research by Pham et al. [2], the bottom-up method was used to perform an emission inventory for the Ho Chi Minh City seaport, which includes 38 ports, 67 buoys, and four anchorage areas. This research will continue to apply the bottom-up method to increase the accuracy of the emission inventory results.

Ocean-Going Vessel (OGV)

The information collection method was based on the approach used to assess the impact of CO₂ emissions from maritime transport activities in the western strait of Singapore during the COVID-19 period, using voyage data from the AIS and information from the Singapore Maritime Data Hub (SG-MDH) [10]. This method was also used for an emission monitoring algorithm based on the actual speed of ships in Korea’s vessel speed reduction program. Data on port calls were obtained from the Port Management Information System (PORT-MIS) and the General Information Center on Maritime Safety and Security (GICOMS), and detailed ship specifications were collected from the Korean Register (KR) and Korea Maritime Safety Authority (KOMSA) [11].

In this study, ship emissions were calculated only for the periods when ships were hoteling and maneuvering in front of the port water. Therefore, general ship declaration information was obtained from the National Shipping Procedure Declaration Portal in 2022 [12]. The dataset was validated by cross-checking vessel call statistics with annual port reports. The CO₂ emission inventory for ships follows the equation provided by the U.S. Environmental Protection Agency (EPA) [13].

$$EOGV = P \times A \times EF \times LF \quad (1)$$

Where E_{OGV} : Emissions from ships (g); P: Engine power (kW); A: Operating time (hours); EF: Emission factor (g/Wh); LF: Engine load factor (%).

According to survey results, most of ships operate within Soai Rap channel use marine diesel oil (MDO) with 0.5% sulfur content by mass. While the main engine supports vessel propulsion at sea, the auxiliary engine provides power for other onboard activities such as operating ship cranes and supplying electricity for crew accommodation. In this study, ship emissions during voyages were considered only for the maneuvering phase, specifically when vessels performed turning operations at slow speeds sufficient for steerage in front of port water. Based on the ship’s operating conditions, the emission factors for propulsion engines (used when ships are cruising or maneuvering) and auxiliary engines (used when ships are at berth/cargo handling) using MDO with 0.5% sulphur content by mass are given in Table 1.

Table 1. Emission factors for propulsion and auxiliary engines of ocean-going vessels [13]. For the propulsion engine, when the vessel is operating in medium-speed (MSD), the emission level is higher than in slow-speed (SSD).

Emission factor for propulsion engines (g/kWh)	Slow-speed (SSD)	589
	Medium-speed (MSD)	649
Emission factor for auxiliary engines (g/kWh)		686

Cargo Handling Equipment (CHE)

Cargo handling equipment at ports varies widely depending on the cargo type but is typically high-powered to optimize vessel cargo operation time. Container terminals commonly use cranes and forklifts, whereas specialized liquid berths mainly use generators to power pumps. To conduct an emissions inventory using the activity-based method, it is necessary to obtain information on the quantity, technical specifications of cargo handling equipment, and the number of operating hours per year, collected from the port operators [14]. The EPA-guided inventory equations for emissions from port cargo handling equipment are presented as follows [13]:

$$ECHE = EF \times kW \times LF \times A \quad (2)$$

Where E_{CHE} : Emissions from cargo handling equipment (g); EF: Emission factor depending on equipment age (g/kWh); kW: Rated engine power (kW); LF: Engine load factor (%); P: Maximum power (kW); A: Operating time (hours).

Through a survey of port companies in the study area from February to March 2024, the authors collected data on the engine power and year of manufacture of the handling equipment. The equipment specifications dataset was validated against port records and port operator interviews. The emission factors for cargo-handling equipment depend on the type of equipment and fuel. The emission and engine load factors for the cargo-handling equipment are listed in Table 2.

Table 2. Emission factors for cargo-handling equipment according to the type of equipment [13]. Load factor is the ratio of average operating power to maximum rated power, reflecting that engines rarely run at full capacity; this study uses the same equipment-specific load factors as previous emission inventories.

Equipment type	Emission factor (g/kWh)	Engine load factor (%)
Crane	705	0.43
Forklift (diesel)	779	0.59
Generator (diesel)	705	0.43
Gantry crane (RTG)	779	0.21

QGIS Method

QGIS was applied because of its open-source nature, availability of geographic base maps, and intuitive visualization capabilities [15]. Furthermore, after mapping the emissions data, it is easy to export the spatial dataset and append the emissions information from other sources. This facilitates the development and planning of local air quality management strategies. In 2023, Isinkaralar [4], used QGIS to analyze the urban dynamics affecting land surface temperature and climate hazards in the coastal zones of Portugal. To perform scenario analysis and mitigation planning through QGIS, there 3 main steps that shall be carried out: (i) Data collection and integration: gather spatial data, compile emission data, import both spatial and tabular data into QGIS for integration; (ii) Georeferencing and layer management: align different datasets to a common coordinate reference system (CRS) and organize data into thematic layers; (iii) Spatial analysis of emission sources: use buffer analysis to assess the influence zones of major emitters. Spatial joins were performed to link the emission data with geographic locations and generate heatmaps or density maps to visualize high-emission areas.

Results and Discussion

Results

Overall, ships emitted 1.116 million tons of CO₂ in both the hoteling and maneuvering modes, while cargo handling equipment emitted 4.344 thousand tons of CO₂. As noted by Ho et al. [16], seaport emissions represent a significant source of pollution in Ho Chi Minh City, with adverse impacts on public health and the environment. By ignoring emissions from ships during the underway condition, the results reflect that emissions from ships operating in the Soai Rap channel are still higher than those from cargo handling equipment. The detailed emissions at each location are presented in Table 3 and Figure 4.

Table 3. Detailed CO₂ emissions of seagoing vessels (classified by operating modes) and cargo-handling equipment by groups in Soai Rap channel. The emission intensity per ton of cargo (tons of CO₂ per ton of cargo handled) for each port indicates the environmental efficiency of port operations in 2022.

Location	Oceangoing vessel			Emission intensity per ton of cargo
	Maneuvering (tons)	Hoteling (tons)	CHE (tons)	
Cement ports				
FU-I Cement Port	0.54	7.21	-	1.06
Thang Long Cement Port	7.26	670.22	1,232.59	0.08
Nghi Son Cement Port	37.60	10,845.18	584.92	0.11
Ha Long Cement Port	15.45	2,200.28	753.42	0.13
FICO Cement Port	19.92	421.92	677.54	0.09

Location	Oceangoing vessel		CHE (tons)	Emission intensity per ton of cargo
	Maneuvering (tons)	Hoteling (tons)		
Chinfon Cement Port	8.20	1,200.91	-	0
General cargo/ container ports				
Long An Port	49.97	2,378.71	354.79	0.26
Tan Cang Hiep Phuoc Port	195.60	65,040.26	345.23	0.03
Saigon - Hiep Phuoc Port	18.88	824.31	338.35	0.22
Other specialized ports (RORO, liquid cargo)				
PACIFIC PETRO Port	2.19	166.55	-	0.09
SPCT Port	163.18	8,477.97	57.27	0.02
Calofic Port	8.79	4,079.73	-	0.05
Buoys				
Buoy B.TT4, B.TT5, B.TT8, B.TT9 (Hoang Hai Dang Co.)	29.90	1,292.46	-	0.78
Buoy berths B.PM1, B.PM3 (Phu My Maritime Co.)	9.10	195.28	-	1.11
Buoy SR-6A (Nha Rong Port JSC)	22.41	1,329.21	-	0.10
Anchorage area				
Soai Rap Anchorage (KV4)	32.97	1,444.57	-	20.01
Soai Rap Anchorage (KV12)	5.42	109.87	-	10.15
Soai Rap Anchorage (KV11)	5.47	261.39	-	16.98
Bo Bang Anchorage	205.65	1,014,471.10	-	0.01
Total	838.51	1,115,417.14	4,344.11	

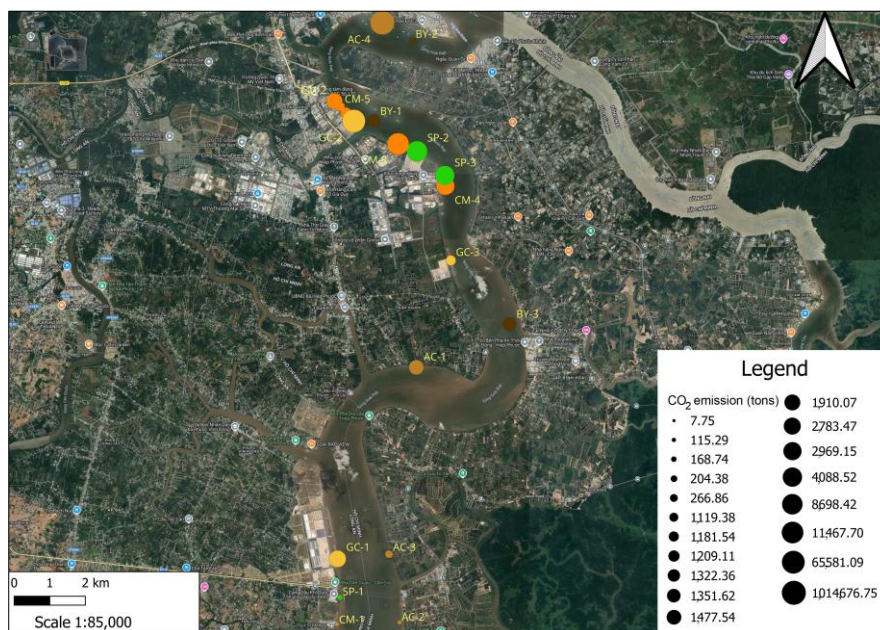


Figure 4. CO₂ on-site emissions in terms of location and size along Soai Rap channel, Southeast Vietnam. The colors reflect the port groups: orange indicates cement ports, yellow indicates container/general cargo ports, brown indicates buoys, brownish yellow indicates anchorage areas, and green indicates other specialized ports. The emission intensity per ton of cargo (tons CO₂ per ton of cargo handled) for each port indicates the environmental efficiency of port operations. This indicator reflects the number of emissions generated per ton of cargo handled in a specific operational area. A lower emission intensity suggests that the area operates more efficiently with lower emissions per unit of cargo, while a higher value indicates greater energy consumption and emissions relative to the handled cargo volume. This metric can be used to compare the environmental performance of different ports and support the development of targeted emission reduction strategies.

Discussion

The total CO₂ emissions amounted to 1.12 million tons, which is 1.19 times higher than the 942.38 thousand tons reported in the 2020 emission inventory of 18 voluntarily participating ports in Ho Chi Minh City [5]. Although only 12 ports along the Soai Rap channel were included in the emission inventory, compared to 18 ports that voluntarily participated in the 2020 inventory, the following factors may have influenced the results: (i) Emissions generated from vessels anchoring at anchorage areas along the Soai Rap channel; (ii) Increased maritime transport activities from 2020 to 2023; and (iii) The use of bottom-up inventory approaches, which provide more accurate results than the top-down approach. Based on the emission inventory assessment, most emissions originated from vessels anchoring in the anchorage area, followed by the port group. Figure 5 presents a chart illustrating the contribution of maritime infrastructure to emissions along the Soai Rap channel.

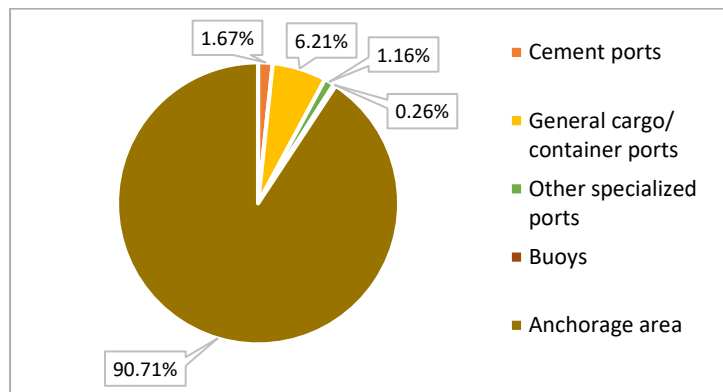


Figure 5. Contribution of maritime infrastructure to CO₂ emissions along Soai Rap channel, categorized by functional groups of ports. The colors reflect the port groups: orange indicates cement ports, yellow indicates container/general cargo ports, brown indicates buoys, brownish yellow indicates anchorage areas, and green indicates other specialized ports.

According to Figure 5, the emission ranking from highest to lowest by group includes anchorage areas (accounting for 90.71%), general cargo/container ports (accounting for 6.21%), cement ports (accounting for 1.67%), other specialized ports (accounting for 1.16%), and buoys (minor emission). Emission inventory results indicate that areas with high concentrations of on-site emissions are Bo Bang Anchorage (89.82% of the total) and Tan Cang Hiep Phuoc Port (5.85% of the total), with ship emissions accounting for up to 99.47% of the total. These two areas with the highest emission levels also corresponded to the highest number of ships, as shown in Figure 2.

The GIS results in Figure 4 also illustrate that the largest representative sources of on-site emissions are Tan Cang Hiep Phuoc Port and Bo Bang anchorage area. These locations highlight a critical distinction: ports are fixed infrastructure, while an anchorage is primarily a water area serving ships waiting to enter the port when the fixed infrastructure is overloaded. As the study area is a secondary channel that is currently being planned for expansion, the implementation of the green port initiative can incorporate various measures, especially those applied during the port construction and investment phases [17]. In port areas, efforts to reduce Greenhouse Gas emissions through the use of batteries, fuel cells, or renewable fuels must also consider the need for renewable sources of electricity or fuel [18]. Although the transition to alternative energy sources is relatively convenient for existing vehicles, it is only effective in reducing certain types of emissions (such as NO_x and SO_x) when using low-sulphur fuels, or may lead to methane slip (emitting more greenhouse gas emissions) in the case of liquefied natural gas (LNG) fuel [19, 20]. On the other hand, shore power supplies electricity from the shore to ships during the hoteling period, a practice widely implemented by large and medium-sized ports to effectively reduce emissions from ship auxiliary generators that rely on fossil fuels [21]. Most zero-emission cargo-handling equipment is powered by batteries or fuel cells, as these technologies offer greater flexibility than grid electricity [22]. Therefore, this study proposes the provision of shore power and electric cargo handling equipment to ships at berths in the Soai Rap port areas. Assuming that emissions from ships (while hoteling at port) and cargo handling equipment are zero as a result of energy transition and the provision of shore power, the projected CO₂ reduction potential for each port under these measures is shown in Table 4.

Table 4. The potential for CO₂ emission reduction by providing shore power and electric cargo handling equipment in the Soai Rap port areas. The potential for CO₂ emission reduction through the proposed measures is expressed as a percentage relative to the initial emission level.

Port	Emission cut down		
	Shore power (%)	Electric handling equipment (%)	Combined measures (%)
Cement ports			
FU-I Cement Port	93.03	-	93.03
Thang Long Cement Port	35.09	64.53	99.62
Nghi Son Cement Port	94.57	5.10	99.67
Ha Long Cement Port	74.10	25.37	99.48
FICO Cement Port	37.69	60.53	98.22
Chinlon Cement Port	99.32	-	99.32
General cargo / container ports			
Tan Cang Hiep Phuoc Port	99.18	0.53	99.70
Saigon - Hiep Phuoc Port	69.77	28.64	98.40
Long An Port	85.46	12.75	98.20
Other specialized ports (RORO, liquid cargo)			
Calofic Port	99.79	-	99.79
SPCT Port	97.47	0.66	98.12
PACIFIC PETRO Port	98.70	-	98.70

Using the above assumption, the mitigation potential of CO₂ reduction measures for port operations along the Soai Rap navigation channel can be summarized as follows: First, although the Port of Oslo differs in terms of port scale, energy mix, and regulatory context, the comparison with the study conducted in 2021 by Bjerkan et al. [23], which reported an 85% reduction in CO₂ emissions through shore power implementation, remains relevant at the level of technological effectiveness, as both cases target emissions from auxiliary engines during the hoteling phase. In the Soai Rap channel, where emissions are strongly proportional to the duration of ship hoteling, the estimated reduction potential from shore power ranges from 35.09 to 99.79%, reflecting differences in waiting times and port functions rather than direct contextual equivalence.

Second, the scenario analysis assumes the additive effects of electrification measures (shore power and electric cargo handling equipment). Wan et al. [24] emphasized that the most effective approach is the integration of shore power with enhanced quay crane efficiency, with priority given to the adoption of shore power systems. In addition to reducing emissions generated by ships during berthing at ports, it also significantly minimizes noise pollution from ship engines, thereby contributing to improving the quality of life of crews and stevedores on board [25, 26]. However, in practice, interaction effects and diminishing marginal returns may occur. Once emissions from ship hoteling are largely eliminated through shore power, further reductions achievable through the electrification of cargo handling equipment are constrained by the relatively small contribution of this source to total emissions, particularly in specialized ports where electricity is already widely used.

Third, implementing these measures implies substantial investment requirements related to berth electrification, crane modernization, and possible anchorage management measures, such as relocation or congestion pricing. Responsibility for these costs is likely to be shared among stakeholders: public authorities (for grid infrastructure and regulatory frameworks), port operators (for berth and crane investments), and shipowners (for onboard retrofit to enable shore power connection). While this study focuses on the technical emission reduction potential, it does not include a cost–benefit or economic feasibility analysis; such an assessment would be essential to determine the optimal allocation of financial responsibility and to evaluate whether the environmental benefits outweigh the capital and operational expenditures. Therefore, future research should integrate techno-economic modeling with emission inventories to support evidence-based policy design for green port development in the Soai Rap corridor.

In alignment with the International Maritime Organization’s strategy to achieve a 40% reduction in CO₂ emissions by 2030, Vietnam has set a target to reduce 37.5 million tons of CO₂ emissions from the transport sector by 2030. The implementation of CO₂ mitigation measures in port operations highlights the potential

for reducing on-site emissions from ports along the Soai Rap channel [8, 27]. However, to establish a direct link to human health and environmental impacts, these results must be incorporated into air pollution models. Following the spatial allocation of air pollutant emissions, air quality modeling was conducted to evaluate pollutant dispersion under meteorological influences, with hourly average concentrations generated for comparison against national air quality standards.

For buoy terminals and anchorages, shore power is generally not feasible because these locations lack connections to onshore electrical infrastructure, rendering grid connections technically and economically impractical under current conditions. Establishing submarine cables, substations, and associated grid connections requires substantial capital investment and entails safety challenges. Argüello et al. [28] pointed out that the longer vessels remain at anchor, the greater negative environmental impacts arising from both air emissions and sewage discharges during ship operations. During the anchoring period, vessels consume fuel to operate auxiliary generators supplying electrical power for onboard domestic services and crew activities while maintaining the main propulsion machinery in a state of operational readiness to enable immediate maneuvering in the event of anchor dragging.

However, there are currently no legal regulations issued by competent authorities (Ministry of Transport or Ministry of Finance) aimed at limiting anchorage time, while charter party contracts often encourage early arrival, thereby prompting ships to wait at anchor before entering the port. The actions recommended for stakeholders are as follows: (i) Maximize the effectiveness of the VTS in coordinating ship speed reductions, thereby minimizing emissions during both transit and anchorage periods [29-31], or to identify ships likely to experience prolonged waiting periods so that they can be assigned to anchorage areas located farther from residential zones and environmentally sensitive areas [32]; (ii) Port states should adopt regulatory measures allowing for the imposition of additional port dues on vessels that remain in anchorage areas for extended periods, thereby creating an economic incentive to reduce unnecessary anchorage time and associated environmental impacts; and (iii) Seaport owners should invest in expanding berth and cargo handling equipment capacity to reduce waiting times, thereby minimizing unnecessary emissions from ships during hoteling.

According to Mahpour et al. [33], there are two main factors that affect cargo operation at port: the number of containers and the number of cranes. A case study at Shahid Rajaei Port in 2019 showed that reducing the number of loaded containers by 20% would decrease the time of cargo operation by 3 to 8%. Additionally, adding one more crane to the existing number of operational cranes reduces the handling time by 5.2%. However, this study has not yet quantified the relationship between emission reduction and improvement in cargo handling capacity at the port. According to the emission inventory results, Tan Cang Hiep Phuoc Port has significant potential for implementing emission-reduction measures. This research is the foundation for continuing other related studies on the effectiveness of air pollution reduction to achieve the green port plan through seaport planning efforts, taking into account the location of CO₂ on-site emissions, as shown in Figure 4.

Conclusions

This study presents the first localized on-site CO₂ emission inventory for the Soai Rap navigation channel, a rapidly developing but understudied secondary maritime corridor in southern Vietnam. Using a bottom-up approach with QGIS spatial analysis, this study demonstrated that ocean-going vessels, particularly during anchorage and maneuvering, are the dominant emission sources, accounting for more than 99% of the total on-site emissions. Bo Bang anchorage emerged as the single largest emission hotspot, underscoring the significance of waiting areas in shaping port-related environmental impacts. The analysis further revealed that the application of shore power and electrification of cargo handling equipment could substantially reduce emissions, with combined measures achieving a high potential reduction. These findings emphasize the need to move beyond purely technical mitigation measures by embedding emission reduction objectives within broader governance and port-planning frameworks. Policy priorities should focus on regulatory instruments that promote shore power adoption, accelerate the electrification of cargo handling equipment, and reduce anchorage times through improved vessel traffic management and port pricing mechanisms. Scientifically, this study advances the understanding of emission dynamics in secondary navigation channels, where anchorage areas are particularly significant. From a policy perspective, the results provide empirical support for advancing green port strategies in Ho Chi Minh City seaport, in line with the national sustainability and climate commitments. Future research should link emission inventories with air quality modeling to better assess environmental impacts and strengthen the evidence base for regulatory actions.

Author Contributions

PTT: Conceptualization, Methodology, Writing - Original Draft, Writing - Review & Editing; **HQB:** Formal analysis, Supervision; **HMD:** Data curation, Validation; **HQB:** Visualization, Investigation; **NTHN:** Investigation, Writing – Review & Editing.

AI Writing Statement

During the preparation of this work, the authors used Grammarly to assist with grammar correction and improve the English language clarity. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

Conflicts of interest

There are no conflicts to declare.

Acknowledgments

This research was funded by Vietnam National University Ho Chi Minh City (VNU-HCM) under grant code C2024-24-10. The authors sincerely thank the Maritime Administration of Ho Chi Minh City for providing relevant information and facilitating the preparation of this paper.

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