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Strategies to Reduce Carbon Footprint in Port and Terminal Operations: Evidence from a Developing Country

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Abstract: The purpose of the study was to identify some practical approaches to help developing nations for leasing their carbon footprint that is left behind as a result of operations at ports and terminals. In this sense, the Bangladeshi seaport of Chattogram serves as a case study that is monitored and analyzed. Investigation on port and terminal procedures and CO_2 emissions is the focus of this study. Conversations with port stakeholders are the main source of data. When it comes to secondary data, it's drawn primarily from past studies and newspaper articles. Approximately 65.8% of the total carbon emissions at Chattogram's port and terminal are attributed to ships anchoring at the port. Other options include port boats with 19%, freight handling equipment with 10% and vehicles with 4.5%. In order to reduce these emissions, the port of Chattogram has determined that cold ironing is the best alternative, and contemporary cargo handling equipment is both cheaper and uses less energy. In order to ensure that port and terminal activities have a minimal impact on the surrounding ecosystem, it is imperative to update outdated pieces of equipment and extend existing terminal facilities. Nevertheless, utilizing renewable fuels (30% biofuels with currently used diesel) can be an effective solution for lowering the carbon footprint of other types of machinery such as forklifts and harbor craft. Furthermore, developing countries may join and coordinate with the LEARN (Logistics Emission Account and Reduction Network) project to enhance and globalize their efforts to reduce their carbon footprint through emission measurements, reporting, and verification (MRV).

Keywords: Carbon footprint; Cold ironing; Alternate fuel; GLEC framework.

INTRODUCTION

Carbon footprint is the total amount of greenhouse gases produced by human activity, usually expressed in equivalent tonnes of carbon dioxide (CO_2). Globally, the largest sources of carbon footprint are industrial processes, multifunctional transportation, and shipping. In addition to contributing to local air pollution, ship emissions have a global impact on climate change (Innes and Monios, 2018). Marine engines produce a variety of gases including CO_2, CO, NOx, SOx, hydrocarbons (CH), and particulate matter (PM) from the combustion of fossil fuels such as oil and gas (Monteiro et al., 2018). International shipping is responsible for around 2.1% of global greenhouse gas emissions, a figure that might rise by 50 to 250 percent by the year 2050 (International Maritime Organization, 2014) . 15% of the world's NOx emissions and 5-8% of the world's SOx emissions are caused by shipping (Zis et al., 2016). A major portion of Shanghai's emissions are coming from Shanghai port 12.4% SO_2, 11.6% NO_x and 5.6% $PM_{2.5}$; from Fung et al., 2014) whereas 28% NO_x emissions of the city are generated from the port of Hamburg (Hamburg Port Authority, 2019) .

The quantity of GHG emitted by world's merchant fleet in 2008, was similar to that produced by an industrial nation, the size of Germany. Additionally, the shipping sector is responsible for 3.9 percent of the world's total production of carbon dioxide, which is equal to 1,260 million tons of CO_2; as a result, it is considered to be one of the single major sources of anthropogenic carbon emissions (Budiyanto et al., 2019) . About 127 thousand tons of carbon dioxide (CO_2) were released by China's port districts alone (Wan et al., 2017).

In the maritime sector, port and terminal activities are a major source of carbon emissions. At seaports, just 1% of total shipping emissions are released (Chen et al., 2013). Although many port authorities fail to recognize the significance of sustainable development, no meaningful controls on greenhouse gas emissions have been implemented in the port and shipping sectors (Wan et al., 2017). United Nations Climate change conference in 2009 advocated the notion of a green port (or low-carbon port). Clean and efficient port and terminal operations are currently the top priority for maritime nations to promote green environment and regional competition. This endeavor has also been bolstered by the IMO's (International Maritime Organization) goal of reducing carbon emissions by 50 percent by 2050. Sustainable, efficient, and competitive contemporary ports rely on renewable energy and automation, which is widely regarded as the solution to this problem. The cost of automating port and terminal operations, especially in poor nations, is a major factor. Alternatives to green efforts (e.g., reducing energy waste, using renewable energy, controlling intentional and unintentional pollution) may lessen the negative externalities of overburdening the port's budget. It is possible that there are various alternatives to attempting green effort (such as restraining purposeful and accidental pollution, reducing the waste of energy, making use of renewable energy, etc.), which can, nevertheless, lessen the negative externalities of placing an undue weight on the port's limited budget. Another way to prevent energy waste in green initiatives is to run awareness campaigns among the various stakeholders on a regular basis. Low-carbon economy is a key strategy to tackle environmental challenges (Wan et al., 2017).

World Economic Forum calls Bangladesh one of the fastest-growing economies. The previous decade has seen a remarkable transition from an agricultural economy to an industrial one. That's a huge boost for the port of Chittagong's importance! To handle around 92% of the country's export and import, the berths are used virtually continuously around the clock. As a result, environmental sustainability is a concern that cannot be ignored. There has been a dramatic shift in public opinion in recent years toward a greener planet. There is a lot of worry about sustainable port and terminal activities as well as the maritime habitat. More and more, ships from the richer nations of the globe are eager to dock at environmentally-friendly ports. Developing nations, in particular, need to find ways to minimize their carbon footprint in port and terminal operations that are both practical and affordable. Some practical strategies to lower the carbon footprint of port and terminal operations without placing too much burden on the limited resources of developing nations like Bangladesh will be sought out in this research. This article will then assess the GLEC (Global Logistic Emission Council) framework at the Chattogram port using LEARN (Global Logistic Emission Council), key informant interviews, and SWOT analysis in order to come up with some reasonable suggestions.

MATERIALS AND METHODS

Brief history of the port

Arab traders gave the city of Chattogram the name "Shetgang" and the port the name "SAMANDAR/SAMUNDA" in the 9th century as a consequence of the growth of the port in that century. Both names are still in use today. Porto Grande was given its name in 1517 by the Portuguese when their ship "LOPA SOANA" arrived. In 1702, the harbor of Chattogram was first visited by a Dutch ship. Britain designated Chattogram Port as an important port in the area back in 1928. In 1947, the port was Pakistan's only trading route to East Pakistan. There were seven new jetties and a handful of pontoon moorings built by 1950. "Chattogram Port Trust" was founded in 1960. The Chattogram Port Authority (CPA) was established as a result of the Bangladesh government's "Port Authority Ordinance 1976" adopted following the liberation war in 1971.

Study area and present outlooks of the port

To better understand how to operate a port and terminal in a way that minimizes its impact on the environment, researchers used the port of Chattogram as a case study. The port of Chattogram is Bangladesh's largest seaport. As a result, it's the busiest port in the Bay of Bengal area, too. The river Karnaphuli's estuary lies beside the port. The outermost port harbor is roughly 7.4 nautical miles away. In addition to being Bangladesh's main seaport, it serves as a major gateway for international trade. According to the port overview for 2017–2018, it is estimated that it handles around 92% of the national annual transshipment. Bangladesh's government receives 33 percent of its income through CPA (Ferdous and Das, 2018).

In 2021-22, the Chattogram Port handled over 3.55 million TEU worth of containerized goods, representing a 5% increase over the previous year's total. Chattogram is now ranked 67th in the world for containerized cargo handling (Lloyd’s list 2020). According to the port's website, For the previous five years, the growth rate has stayed nearly constant. It indicates that the port will soon be a victim of its own prosperity. To be sure, the ongoing Matarbari deep seaport project, the Bay terminal, and the Patenga container terminal will all help relieve some of the stress at Chattogram Port's current container processing capacity of roughly 3.6 million TEU. Therefore, it is fair to say that the port of Chattogram has made a significant contribution to the economy of Bangladesh. For the time being, the terminal is outfitted with 42 Rubber Tired Gantry Cranes (RTG), 18 Quay Gantry Cranes (QGC) and another 02 are in the process of being erected, 07 Reach Stacker (RST), 45 Straddle Carriers, and around 120 forklifts are in use to meet the requirements of the port. It was also discovered that 4000 vehicles visit the port every day to transfer containers back and forth, according to information gleaned from the record of security checkpoints.

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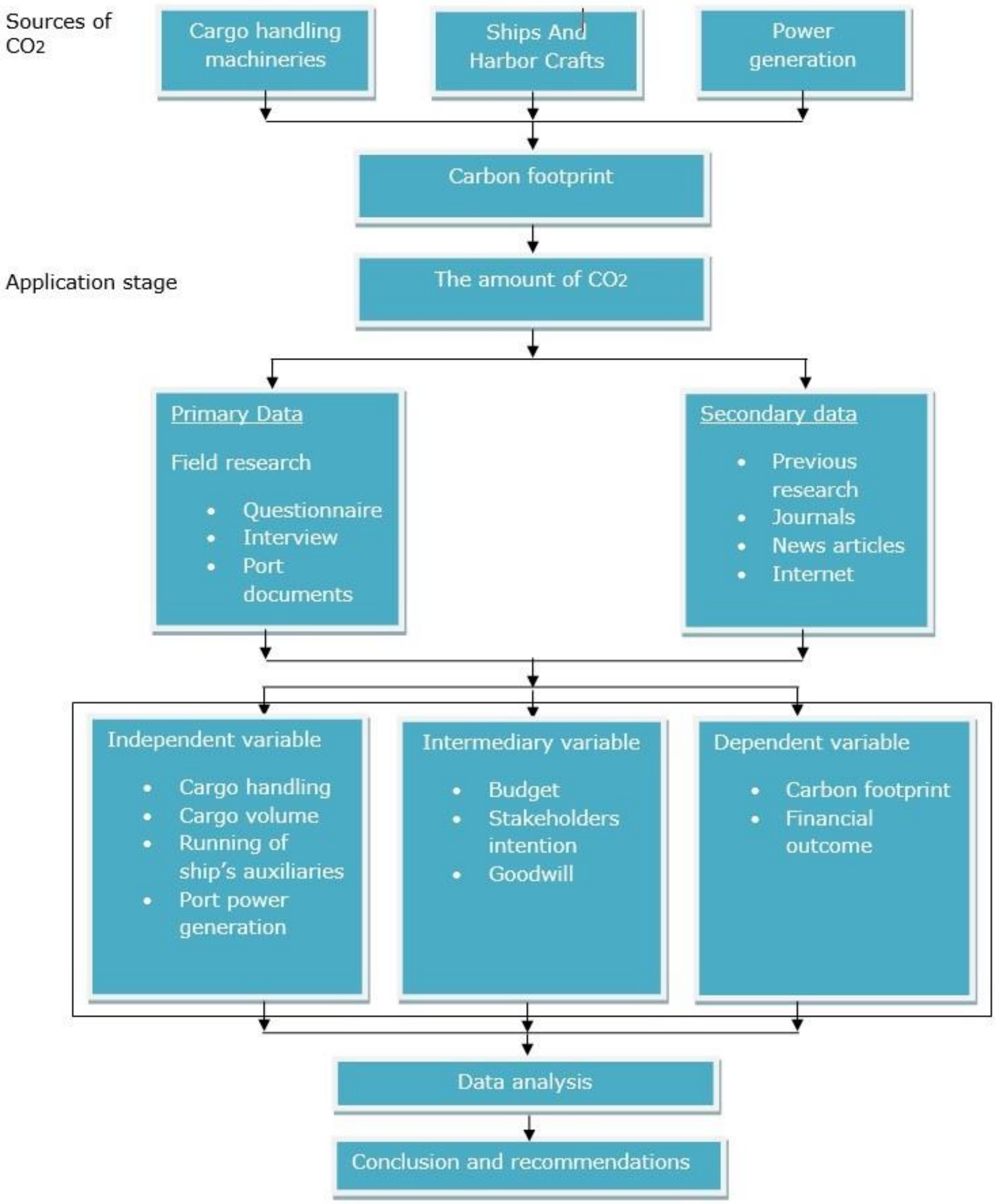

Figure 1: The research framework.

The study has been constructed based on the framework given in Figure 1. Research questions are addressed in every aspect to research finding to figure out a suitable answer. A case study approach has been followed for this research. This research offers a qualitative examination of the influence that port and terminal procedures have, as well as the CO_2 emissions that are associated with those processes. Surveys, inspection, and news outlets are the primary data collection methods used in this investigation. In addition to serving as a guide and precedent, the academic literature was also taken into account when gathering secondary data. Port authority decision-makers have been scheduled to meet with researchers so that they can verify the findings. These people are among the stakeholders: the Director General of the International Mobile Satellite Organization (IMSO), a Terminal Manager, an elected member of CPA's Harbors and Marine Committee, the Chairman of CPA, a Deputy Conservator and an elected member of CPA. When conducting interviews, researchers keep the research questions in mind. Questions, most of which were open ended, were put to them in an attempt to get insight into the problem and some

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possible mitigation techniques. Finally, the answers were recorded and documented for future reference. Face-to-face interviews were favored above other methods. However, telephone conversations were also employed as a means of clarifying any discrepancies that arose as a result of the process of conducting this research. The combustion of fossil fuels to produce the energy required to run terminal operations directly results in CO_2 emissions. This article measures the carbon footprint of port and terminal fuel consumption, including electricity sources. This was made possible by the use of a standard carbon calculator and investigation into previously scientific literature. Based on historical data analysis, consumption data was utilized to verify.

RESULTS AND DISCUSSIONS

Measurement of carbon emission

The amount of greenhouse gas emissions produced by port activities was assisted in being determined by the Chittagong Port Authority (CPA) with the assistance of the Institute of Forestry and Environmental Sciences at the University of Chittagong. This institute received funding from the United Nations Environment Program. They looked at five different modes of travel and services offered by the Chattogram Port while also taking into account the potential for carbon emissions within the port and terminal. However, this paper highlighted following four categories (Table 1) ignoring the locomotives, since these are not directly under administrative control of CPA.

Table 1. Categories of studied transports/services.

No	Classification	Varieties
1	Navigable Seas	All of the ships that are docked at Chattogram Harbor
2	Harbor Craft/vessels	Boats for towing, piloting, harbor patrol, anchoring, etc.
3	Cargo Handling Equipment	Equipment such as forklifts, gantry cranes, rubber tire gantry cranes, and skid loaders are all examples of top and side loaders.
4	Vehicles	Trucks used for loading and unloading cargo at the terminal areas.

According to the Browning et al., (2009) , the following formula was used to calculate carbon emissions from CPA activities:

$$E= P \times LF \times A \times EF$$

Where, E = Emission (gram/year), P = Maximum Continuous Rated Power (kilowatts), LF = Load Factor (percent of vessel's total power in use for each operation mode), A = Activity (hour/year); duration for each operation mode with one year period, EF = Emission Factor (gram per kilowatt-hour); level of emission for each pollutant parameter.

Table 2 summarizes the 2016 total estimated emissions from Chattogram port's port and terminal activities, whereas category-wise emissions have been given as Supplementary Information (SI, 1-6).

Table 2. Emissions of pollutants and greenhouse gases from the Chattogram port and terminal in 2016 (measured in tones).

SL	Category & Number	NOx	CO	PM_{10}	$PM_{2.5}$	SO_2	Black Carbon	CO_2
1	Vessels at berth (4594)	2733.28	217.27	333.54	283.00	4629.00	79.24	257143.10
2	Harbor Craft (62)	1156.36	307.332	32.73	31.746	141.826	8.888	75277.12
3	Cargo handling equipment (512)	210.076	47.907	9.390	9.263	12.371	2.594	40904.30
4	Trucks (48000)							17520.00
Total		4099.72	572.509	375.66	324.009	4783.20	90.722	390844.5

Table 2 shows that carbon dioxide emissions from fossil fuel combustion are much greater than the emissions of any other hazardous gas. Despite the fact that it does not include any hazardous elements, it is the second most dangerous greenhouse gas behind water vapor (Zein & Chehayeb, 2015) . According to Budiyanto et al.(2019) , the combined annual cargo handling capacity of India's main and non-major ports is 792,96 million metric tons. It was further observed that rubber tire gantry emission was the greatest in the two major Mumbai ports tested, Jawaharlal Nehru port Container Terminal (NJPCT and Mumbai Port Trust) (RTG). Located in Jakarta, Tanjung Priok is Indonesia's busiest and most technologically sophisticated port. At current moment, the port is responsible for managing slightly more than half of all of Indonesia's trans-shipment goods. In 2016, the port handled around 6.2 million TEUs worth of goods, while having a maximum capacity of somewhere near 8 million TEUs.

Implication of GLEC framework at the port of Chattogram through LEARN

Emission measurements, reporting, and verification are all part of LEARN's objective to help businesses minimize carbon emissions throughout their worldwide supply chain (Lewis et al., 2017). However, brief perspectives of CPA with compared to LEARN project are shown below:

Measure

Item	Perspectives of CPA
• Supply chain and logistics services	Carbon emissions from Chattogram's port and terminal facilities fall into four categories, as outlined below. Ships, harbor vessels, cargo handling equipment, and vehicles are all found at the terminal's berth. The CPA has determined the amount of time the machines are operational and the amount
• Asset utilization measurement (up/downtime of equipment)	

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• Measure fuel and energy used	of fuel/energy they require.
• GHG emissions calculation	Present emission calculations are based on baseline Air Emission Inventory

Report & Verify

Item	Perspectives of CPA
• Management	Environmental management and sustainable development are high on the agenda of the port, and translates in the construction, reconstruction and development works in a sustainable manner
• Corporate social responsibility reporting	No CSR statement formulated yet.
• Customers	Not provided
• Programs & initiatives	Stakeholders are encouraged through seminars, meetings and through professional courses

Use of Results

Item	Perspectives of CPA
Emission data are used for:	
• Setting targets and trucking emissions	Practiced to achieve by 2030
• Emission reduction strategies	Adopted
• Carbon credit	Not yet
• Risk management	-
• Supply chain optimization	Not yet
• Product labels	Not yet
• Carrier selection	Not yet

According to the investigation, Chattogram port authority uses various LEARN variables. However, these efforts are not well organized or circulated among the international community because of the system they use. Joining in LEARN project and subsequently use of GLEC framework will provide them a suitable platform to establish as one of the environmentally sustainable green ports in the world.

SWOT analysis on the reduction of carbon emission in the port of Chattogram

Evaluation of the company's strengths, weaknesses, opportunities, and threats are all part of SWOT analysis. It is the goal of the port of Chattogram to move forward into the next phase of sustainable growth. It's helpful to focus on strengths and chances to overcome weaknesses and threats in suggestions and tactics. SWOT analysis results are shown in Table 3.

Guidelines for reducing Chattogram's carbon footprint at the port and terminals

This study makes a few suggestions for reducing the carbon footprint of port and terminal operations that are appropriate for developing nations based on an assessment of the interviews with stakeholders. The operations of the Chattogram port and terminal are the ones that will receive the most attention from these proposed procedures. This is not to say that the carbon footprint reduction strategies for emerging nations like India, Pakistan, and Indonesia are considerably different from the port under consideration, but they may be. This study recommends the following: (a) At Ship's Berths arrangement of facility Cold Ironing (b) Mixing Alternate Fuel for Harbor Crafts; (c) Electrifying Terminal Machineries; (d) Discouraging Trucks from Entering Terminals (e) Utilizing GLEC Framework for Carbon Measurement (f) Electrifying Terminal for Self-Power Generation Plants, consider using LNG as a fuel (g) Port Time Reduction for Ships (h) Staff-training.

According to the aforementioned guidelines, lowering carbon emissions at Chattogram port may be seen in Figure 2.

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Table 3. SWOT analysis of the port of Chattogram

Strengths	**Weaknesses**
• About a third of government income goes to CPA • The port has a strong commitment to environmentally friendly operations • The port and terminals are expanding • CPA's tool port management system gives him command over their asset. Because of this, people have the option of reducing their carbon impact.	• Government bureaucracy complications in executing policy choices • Shortage of competent labor • Terminal overcrowding • Absence of legislation on ship's age to call port
Opportunities	**Threats**
• A home economy of 170 million people is easily accessible. • More renowned port in the region. Countries like as India, Nepal, Bhutan and China are already using it for home usage. As a result, there's no need to give up on trying to make money. • Incorporating sustainability concerns into new innovations • Modern technologies are so effective, economical, and environmentally beneficial.	• To expand trade volume through other ports in Bangladesh, such as Mongla and Payra, the government of Bangladesh has placed an emphasis on infrastructure development. Consequently, Chattogram Port's long-term growth may not be as strong as anticipated • The region's geopolitical situation is quite complex.

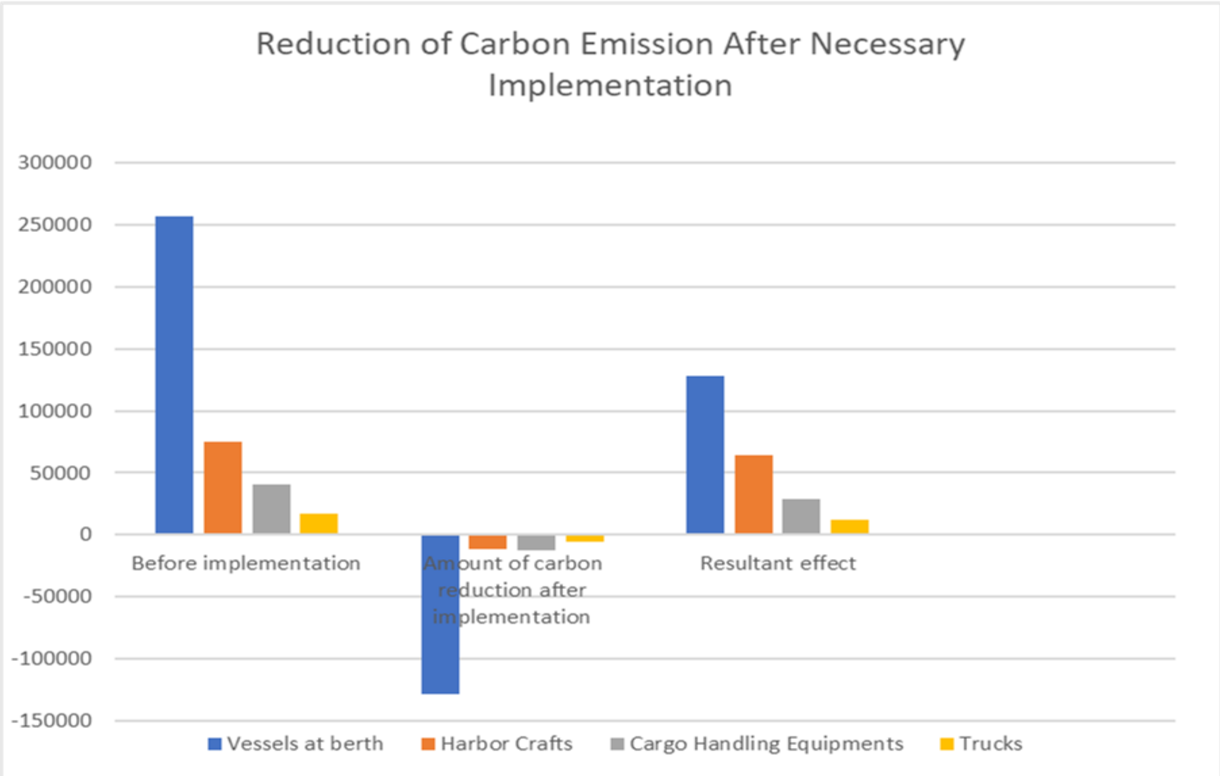

Figure 2. Carbon emission minimization following appropriate action

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Presuming a) 50% of current docks have in-shore power, b) harbor vessels use 30% biofuel, carbon emissions would be 15% lower, c) the use of gasoline that contains 30% biofuel in the cargo handling equipment reduces carbon emissions by 30% overall and d) compliance reduces carbon emissions by 30%.

CONCLUSION

According to the findings, developing countries like Bangladesh may make a significant contribution toward lowering their carbon footprint through the operations of their ports and terminals, despite the many obstacles that they face. The ships at berths were determined to be the primary source of port-area carbon signatures. Since this was an issue, cold ironing was found to be the best solution. This technique is both commercially feasible and efficient in terms of costs. By relying on shoreside electricity rather than onboard auxiliary generators, "cold ironing" minimizes emissions when ships are berthed in port. Connecting to the power grid while the vessel is in port will cut down on the amount of time the auxiliary generators are required to operate, which in turn will lower the expenses associated with their operation and maintenance. Because of the rising cost of fuel due to Russia Ukraine war, using cold ironing as a way to save money. In this aspect, however, the power source for the grid needs to have a low carbon footprint. Additional possibilities include of electrifying the terminal equipment, blending in an alternative fuel, utilizing LNG as a source of power generation, training the workforce, and so on. From conversations with CPA's main stakeholders, it's clear that none of them reject the need for a green port. In addition, the government is interested in making investments in this particular area. The only obstacle is that those who will be doing the task need to be educated, trained, and closely supervised.

Conflict of Interest

Neither a governmental nor private organization contributed financially to this study. There are no conflicts of interest declared by the authors.

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