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Research on Drivers and Barriers to the Implementation of Cold Ironing Technology in Zero Emissions Port

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ABSTRACT: Ports play an important role in connecting the domestic and global economies. Zero emissions port models are actively developed and frequently utilized to fulfill economic objectives while reducing environmental effect. The cold ironing system is one of technological methods assisting ports in transitioning to zero emissions port models. Although a number of ports have successfully implemented it, many other seaports, particularly those in developing countries, continue to face numerous challenges in implementing cold ironing. The aim of this research is to investigate the factors influencing the adoption of cold ironing. The study used a quantitative method, conducting a survey of 215 port managers from the North, Central, and South of Vietnam. The findings indicate that economic incentives and regulation have a positive impact on the adoption of cold ironing at ports. While lack of initial capital and lack of standardization are barriers to the implementation of cold ironing. The last section will look over the study's results and implications in greater detail.

KEYWORDS: Cold ironing, zero emissions ports, regulations, standardization, awareness, sustainability

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Introduction

The fundamental pillar of international trade and a major driver of globalization is marine transport. According to previous research results, approximately 80% of global trade in terms of volume and 70% in terms of value are managed by ports globally. Around the world, there are >2000 ports, and these ports are where the majority of the economic and pollution growth in coastal areas is concentrated. Transport by sea fosters economic growth and boosts regional trade and the industrial sector.[1,2] However, Innes and Monios[3] found that concern over ship emissions in ports is growing, notably for SOx, NOx, and PM rather than CO2. While the latter only contributes a very small proportion to global shipping CO2, the former directly harms local communities. According to the World Health Organization (WHO), air pollution poses a serious threat to human health and is responsible for 3 million annual fatalities.[4] This is significantly impacted by shipping, particularly in coastal locations. According to Zis et al[5], worldwide shipping is responsible for 5% to 8% of SOx emissions and 15% of NOx emissions, both of which have a negative impact on the environment and human health. The shipping industry is a substantial contributor to air pollution, which results in long-term sickness and death from asthma and other chronic illnesses, killing 40 000 people annually in the UK alone.[6]

Over the past few decades, various strategies have been developed to prevent or reduce the emissions and related external costs brought on by shipping, more specifically, in ports that are close to highly inhabited regions.[7] Cold ironing is frequently viewed[8,9] as one method for cleaner and more ecologically friendly marine transport. This is one of the techniques to minimize such emissions from boats in ports. The usage of onshore electricity can eliminate noise, vibration, and greenhouse gas (GHG) emissions from ports and harbors as well as other air pollutants including NOx, SOx, and PM.[10-18] Nevertheless, despite the fact that cold ironing regulations have been extremely successful in big ports like Los Angeles, Seattle, and Rotterdam, Asian countries, like Vietnam, have been unwilling to implement them.[19] The high initial cost of cold ironing is one of the big challenges to adoption. Prior studies predicted that investment costs in the ports of Aberdeen and Copenhagen would be £6.6 million and €37 million, respectively, which created a barrier for ports in developing nations like Vietnam.[3,20] Developing nations with limited resources, like Vietnam, struggle to allocate resources between diverse goals like economic development and environmental conservation. Many countries have prioritized economic goals above environmental issues.

Research on cold ironing systems in developed countries is progressing significantly, with a focus on reducing emissions from ships at berth and enhancing port sustainability. In Europe, several ports are advancing in cold ironing technology. For instance, a study on Croatian ports indicates that while the technology is feasible, substantial investments and collaborative efforts are necessary to overcome implementation challenges. Approximately 40% of state-owned ports have the minimum required electric connection power, highlighting the need for infrastructure upgrades.[21] Similarly, ports in the Adriatic Sea, such as Trieste, are exploring cold ironing to reduce greenhouse gases and other pollutants. The economic, regulatory, and environmental factors influencing these initiatives are being closely analyzed to facilitate broader adoption.[22] In Germany, Siemens has been instrumental in developing cold ironing solutions at the Port of Hamburg. Their SIHARBOR system is designed to be compatible with any ship's electrical system, offering a flexible and effective solution to match the frequency and voltage requirements of various vessels. This system helps significantly reduce air pollution and noise, benefiting the densely populated areas around the port.[23] The United States also sees advancements with projects like the BlueBARGE initiative, which aims to provide a cost-effective cold ironing solution using a barge-mounted system. This approach is particularly innovative as it can be moved to different locations, providing flexibility and reducing installation costs at individual ports.[24]

Given the benefits of cold ironing, it is crucial to address these challenges through collaborative efforts, funding mechanisms, and policies that encourage the adoption of cleaner technologies in ports worldwide, including those in developing countries. However, experimental studies on cold ironing, especially in developing countries, are indeed limited. The aim of this research is to examine the primary drivers and barriers to the adoption of cold ironing in emerging countries. Additionally, this study uses a quantitative approach that hasn't been used before to identify these factors. The research results might be an important main basis for the government and port authorities as they develop policies to promote the implementation of sustainability criteria for the port.

The rest of this study is divided into the following sections. The definition of cold ironing and its sustainability will be covered first in part 2. In this section, the author will discuss the elements that contributed to the acceptance of cold ironing. Section 3, it is explained how to approach managers working in the 10 major ports in Vietnam's North, Middle, and South to ask for information. This section will also demonstrate how to analyze data. The study's conclusions are displayed in Section 4. Section 5 will demonstrate the contribution, practical and managerial application, and future research direction.

Literature Review

The section will introduce green ports as part of the sustainable operations plan, aiming to meet both economic and environmental objectives. Specifically, this content discusses the use of technical methods to reduce the environmental damage caused by pollution from the port. Furthermore, we will present the cold ironing technology, which has been developed to effectively eliminate emissions from ships at certain ports. Finally, the authors will discuss the factors that promote or hinder the adoption of cold ironing.

Green port

According to Jeevan et al,[25] ports play a crucial role in the seamless operation of international trade and commerce by serving as connections between various nations and continents, enabling the interchange of goods and commodities, and promoting economic expansion and advancement. On the other hand, traditional port activities have a considerable negative influence on the environment due to things like energy consumption, trash disposal, water pollution, greenhouse gas emissions, and land occupation.[26,27] Through a number of annexes to the MARPOL convention, which was initially published in 1973, the International Maritime Organization (IMO) has progressively implemented numerous measures to limit emissions in maritime transport.[28]

Various activities at ports are also encouraged by numerous countries and international organizations, including the EU. Apart from the guidelines issued by the European Commission, the European Ports Organization (ESPO) advocates for environmental management, policy, and planning in ports throughout Europe. In 1999, ESPO launched the EcoPorts Foundation, a network of European ports that highlights important environmental features of port operations, goods, and services, in an effort to promote the Green Guide. The Environmental Management Manual (EMH) is a manual for environmental management that was created in the Americas by the American Association of Port Authorities (AAPA), which has 150 members in North, Central, and South America.[29]

Green port is a key idea that has been put forth after a lot of work by several organizations to help ports achieve their environmental and economic objectives. As per the description given in Ying and Yijun's[30] study, a green port is a kind of seaport that is planned with consideration for both the economic benefits and the environmental impact. The environmental stability of these ports is ensured, as is the environmental friendliness of their operations. Economic and environmental benefits must be taken into account concurrently when building a green port, without one being given priority over the other. As a result, the construction of these ports necessitates an emphasis on environmental protection, sustainable resource development, and energy saving. Green ports, in particular, are those that use innovative technology to reduce emissions that pollute the environment. In general, green ports are those that prioritize a healthy environment, rational resource usage, low energy consumption, low pollution emissions, resource efficiency, and environmental preservation.[31] Green ports have quickly attracted the attention of academics and port operators throughout the world. For example, in January 2005, the Port of Long Beach implemented a green port strategy that established a basic foundation for ecologically friendly port operations.[32]

Previous research has shown that green ports must discover strategies to decrease greenhouse gas emissions because they are one of the most important challenges in reducing shipping's environmental effects.[33] According to Parhamfar et al,[27] there are 3 major techniques to reduce greenhouse gas emissions at sea, which contribute to green port development: (1) Technical measures: These include the use of fuel cells, biofuels, and cold ironing (the process of connecting a moored vessel to shore power, allowing ships to turn off their engines and reduce emissions while still receiving the power needed for onboard operations), as well as more efficient propulsion and hull construction[34]; (2) Market-based policies: These consist of carbon taxes and emissions trading programs; and (3) Operational measures: such as enhanced fleet planning, efficient routing, speed optimization, and other logistics-based tasks.[35]

To achieve operational sustainability, the triple-bottom-line strategy must be considered. This method mandates a minimum level of performance in the environmental, economic, and social dimensions.[36] Green port development encourages social advancement, environmental resource protection, as well as immediate and long-term economic growth and stability.[30,37-39] The core of green port development is the control of the conflict between meeting human needs and preserving the integrity of the ecosystem. The green port performance might be measured using a variety of indicators, but over the past 3 decades, nothing has changed concerning these. The majority of academicians have focused on managing air, noise, and water pollution.[40-47]

A strong basis for green port strategies has been established by the numerous research that has been done on the technological innovations, drivers, and challenges of green ports. In this paper, we concentrate on cold ironing as a technological advancement that can help ports reduce emissions.

Cold ironing

Vessels can apply for cold ironing, also known as the onshore power supply (OPS) or shore-side electricity, by connecting to it instead of utilizing their auxiliary generators to provide power for hoteling (SSE). While the ship is loading or unloading cargo, this technique permits the continuing electrical powering of other equipment, such as emergency equipment, refrigeration, cooling, heating, and lighting.[3]

Innes and Monios[3] demonstrated that the benefits of cold ironing from an environmental and financial standpoint have been supported by prior research that has been published for the ports of Los Angeles (US), Oslo (Norway), Aberdeen (Scotland), Copenhagen (Denmark), and Kaohsiung (Taiwan).[20,39,48,49] The reduction of local and global pollutants, as well as noise, are the main benefits of cold ironing technology for the environment.[11,50,51] Cold ironing can lower CO2, SO2, NOx, and BC emissions by 48% to 70%, 3% to 60%, 40% to 60%, and 57% to 70%, respectively, according to research by Zis et al.[52] Styhre et al[53] calculated that the emissions were 150.000, 240.000, 97.000, and 95.000 tonnes of CO2 for the ports of Gothenburg, Long Beach, Osaka, and Sydney, respectively. In Italy's port of Taranto, cold ironing might reduce NOx and CO2 emissions by 1.097 tons per year and 25.686 tons per year, respectively.[54]

A framework for the economic feasibility of cold ironing investment is suggested by Dai et al,[55] which also claims that cold ironing may help ports make money through reduced CO2 emission trading. Furthermore, using low, medium, and high fuel price scenarios, Zis[34] examined 2 roundtrips of the Ro-Ro ship between ports A and B in Sweden and Belgium. The results show that investing in cold ironing is economically favorable for the ship at medium and high fuel costs, but that at extremely low fuel prices, the energy cost savings are inadequate to recoup the investment over the anticipated lifetime.

In terms of society, cold ironing is one useful strategy for reducing environmental pollution, which eventually reduces the number of people dying from air pollution-related conditions like asthma, lung cancer, heart attacks, and chest pain.[10,56,57] The major advantage of cold ironing is that it minimizes the socioeconomic costs associated with treating illnesses caused by ship air pollution. Several studies have examined the cost of ships' emissions.[13,20,58-61] Cold ironing's long-term benefits in terms of improved public health, environmental quality, and regulatory compliance can outweigh these expenses and lead to savings for society as a whole. For instance, Chatzinikolaou et al[60] estimated the total external health cost to be roughly 25.3 million euros in the Greek port of Piraeus, of which more than half (61%) was attributed to particulate matter.

ExternE[58] estimates that the external cost of ship-related air pollution at the Venice port is 24 million euros. As a result of airborne pollutants from container ships traveling various routes, Friedrich and Bickel[61] calculated the external cost of inland shipping for the Netherlands and determined that it was 321 million euros, as well as the cost per 100 km: On the routes Felixstowe-Rotterdam (1200 €/vkm), Rotterdam-Felixstowe (1050 €/vkm), Piraeus (9300 €/vkm), Iraklion (900 €/vkm), Aegean Sea (1000 €/vkm), and Felixstowe-Rotterdam (1050 €/vkm). The CAFÉ project series (2005) calculated a 45 billion euro external cost of air pollution from maritime transport for the European Seas. In the UK, the annual cost of air pollution might be £54 billion.[3] Air pollution-related health problems have a significant financial impact on both society and business. Each year, these medical costs in the UK reach >£20 billion.[6] By providing shoreside electrical power to ships at berth, cold ironing technology not only reduces emissions and noise from ships but also creates a more pleasant and sustainable environment for workers and communities in port areas, which positively contributes to the health and productivity of the workers.

Vietnam is now in the process of implementing several renewable energy initiatives, focusing mostly on wind power, solar electricity, and small hydropower. First, wind power projects have been implemented in various locations, including the Bac Lieu offshore wind farm, which currently has a capacity of 99 MW and is projected to expand to 400 MW. Another example is the Khai Long wind farm in Ca Mau, which currently has a capacity of 100 MW and is expected to increase its total capacity to 300 MW. Additionally, the Ke Ga wind power project in Binh Thuan, with an anticipated capacity of 3400 MW, is being carried out by Vietnam Oil and Gas Group (PVN) in collaboration with foreign investors.[62-65] Second, solar power is a type of renewable energy initiative. As to the revised Power Plan VII, the projected solar power capacity in Vietnam is anticipated to reach 4000 MW by 2025 and 12 000 MW by 2030. Presently, there are other expansive undertakings underway, such as the construction of multiple solar farms in Ninh Thuan and Binh Thuan.[66] These projects collectively have a capacity of several thousand megawatts.[64,67,68]

Finally, renewable energy sources are derived from small hydropower plants. Vietnam now possesses about 1000 prospective sites for small-scale hydropower projects, with electricity capabilities ranging from 30 to 100 MW.[69] In all, these sites have a combined capacity of over 7000 MW. The current installed capacity of tiny hydropower is around 2300 MW as of 2015. It is projected to reach 27 800 MW by the year 2030, according to the World Bank.[70] These projects not only enhance Vietnam's energy supply capacity but also significantly contribute to the objective of lowering greenhouse gas emissions and promoting sustainable development in the face of escalating climate change.[65,67]

Factors influencing the implementation of cold ironing

Lack of initial capital. Financial obstacles include all expenditures associated with the facility before, during, and after the implementation process. It comprises investment costs, costs for operation and maintenance, and costs for electricity. The costs of berthing, infrastructure, and ship-side retrofits make up the entire investment cost.[71]

It has been demonstrated in several studies that installing a cold ironing system can be expensive. For instance, investment costs were expected to reach £6.6 million and €37 million, respectively, in the ports of Aberdeen and Copenhagen.[3,20] The World Ports Climate Initiative (WPCI) estimates that yearly operations and maintenance expenses account for 5% of the project's overall investment costs.[72] Different countries have different electrical policies, which has a big impact on how much it costs to power the berthed ships.

Another obstacle can be the lack of energy in certain cities or regions. High-voltage cold ironing systems frequently cannot be supported by local grids. This is particularly true in smaller cities. According to Krämer and Czermański,[73] in order to justify cold ironing system investments in these areas, further multi-million dollar investments in new electrical networks and transformation substations are required. Building cold ironing systems will be extremely difficult for ports, especially those in developing nations, as it will need a huge initial financial investment. Therefore, the author argues that:

> *Hypothesis 1: Lack of initial capital is negatively related to the implementation of cold ironing.*

Lack of standardization. A further barrier is provided by different technological concerns related to the lack of standardization.[10,71,73,74] Matching shore electricity's voltage and frequency to ship power is the main problem in developing harbor networks. This relates to the compatibility of electrical parameters: various foreign shipyards do not have the same requirements for voltage and frequency. Some ships utilize 220 V at 50 Hz, some at 60 Hz, while yet others use 110 V. It is necessary to have a shoreside power transformer that complies with the High Voltage Shore Connection (HVSC) standard voltage, but this transformer also has to have minimal no-load losses since it is still active even when a ship is not connected to shore power.[75] A frequency converter is needed to deliver electricity to ships running 60 Hz aboard in harbors with 50 Hz power supplies and vice versa in order to match the frequencies of the onshore and onboard power systems. Due to the fact that a frequency converter is one of the most expensive pieces of harbor grid equipment, it must be developed in a modular manner to satisfy the diverse power requirements, but not necessarily by standard size.[76] Furthermore, the primary distribution voltage varies from 440 V to 11 kV. Vehicle carriers require a few 100 kW of power, whereas passenger ships or reefer ships may require a dozen or more MW. In addition, there is presently no uniform standard for connectors and cables.[74] The absence of technological standards will result in an increase in the number of converters and the expense of cold ironing. Inadvertently, this prevents the practice of cold ironing at ports.

> *Hypothesis 2: Lack of standardization is negatively related to the implementation of cold* ironing.

Lack of awareness. According to Glavinović et al,[21] the implementation of cold ironing presents numerous difficulties. Stakeholders, especially financial actors like institutional investors, banks, and venture capital firms, may lose interest in and commitment to promoting the implementation of cold ironing if they lack or do not have adequate information and awareness about its potential, costs, technologies, and markets. For instance, studies on the development of wind energy have demonstrated that one of the challenges to its implementation is investors' misunderstanding of these projects.[77-80] For all parties involved, especially those who will be investing significant amounts of money in this project, having a thorough awareness of the project's viability, advantages, and expenses will be crucial.

Implementing cold ironing can be restricted by a lack of knowledge about environmental protection laws and the government's long-term focus on port development. In order to make shoreside electricity attractive to all parties concerned, the local government has also acknowledged the need to change the legal framework and increase awareness at the national or even European level.[81] Additionally, there is less chance of developing a cold ironing system since customers who support a green economy are not informed about the port's environmental effects, health-related problems, and environmental advantages of cold ironing. For example, the study of Diógenes et al[78] pointed out that the lack of this information often makes it difficult to quantify project costs, as well as project implementation. A full technical understanding of the cold ironing system is also important. Missing information on technical standardization was also a difficulty in the development of cold ironing.

Hypothesis 3: Lack of awareness is negatively related to the implementation of cold ironing.

Economic incentives. In the past, morality and culture alone have not been sufficient to promote the widespread use of cold ironing.[82] Port authorities should offer incentives to encourage cold ironing and reduce externalities by boosting cost integration. However, these incentives can be generated in numerous ways and implemented by parties acting at various levels, such as the government and international legislative bodies like the IMO.[83] The government, for example, might encourage ports to adopt cold ironing by lowering taxes, power costs, and loan interest rates. For example, Williamsson et al[84] explained that the gap between fuel costs and the cost of utilizing electricity is the key economic driver pushing the use of cold ironing.[85] It has been reported that certain ports, like the port of Gothenburg, have changed to more alluring cold ironing by providing free power. A major factor in enticing potential ports to cold ironing is the reduction in fuel costs.[3] Local energy prices have a big impact on how alluring cold ironing is, making it more alluring in countries like Norway that have reasonably priced, clean power.[86] However high local electricity costs, such as those in Southern Europe, effectively act as a localized barrier to adoption.[22] Financial incentives play a crucial role in accelerating the development of renewable energy projects and making them commercially viable.[78,80,87]

By addressing the barrier of high investment costs through a combination of financial incentives, collaboration, technology development, and risk mitigation measures, it may be possible to overcome this obstacle and accelerate the adoption of cold ironing technology in the maritime industry.[71] The cost of implementing cold ironing systems can indeed be substantial, often ranging from $2 to $6 million or even higher depending on the specific requirements and scale of the port. For many ports, especially smaller ones or those in developing regions, this initial investment may exceed their available funds. Consequently, the author proposes that the government will encourage ports to make use of cold ironing technology for environmental preservation through the employment of incentives such as interest rates, tariffs, and administrative procedures.

Hypothesis 4: Economic incentives are positively related to the implementation of cold ironing.

Regulation. A law in California known as the "At-Berth Regulation," which aims to lower emissions from auxiliary motors while lodging, has pushed the usage of cold ironing. The primary solution is to employ cold ironing or equivalent technologies that reduce NOx and PM emissions by the same percentage (70% at now, up to 80% by 2020). Similar regulations requiring ships to utilize ultra-low sulfur fuel or to achieve comparable reductions using alternative technologies, such as cold ironing as an option, have been in effect in European ports since 2005.[34]

According to Innes and Monios,[3] all nations are required to adhere to the fundamental legal standards specified by the IMO. The IMO established the International Convention on the Prevention of Pollution from Ships, which has a long history of preventing ship pollution (known as the MARPOL Convention).[8] Vietnam's commitment to the International Maritime Organization (IMO) and its efforts to protect the marine environment are commendable. Ratifying 24 IMO Conventions and Protocols demonstrates the nation's dedication to international maritime standards and regulations. By being an active member of the IMO, Vietnam contributes to global maritime safety, security, and environmental protection efforts. The development of laws and rules further underscores Vietnam's commitment to safeguarding its marine ecosystems, which are vital not only for its own coastal communities but also for the broader global environment. The 2015 Vietnam Marine Law appears to be a comprehensive legal framework aimed at ensuring the sustainable management and protection of Vietnam's marine resources. By mandating compliance with its provisions, as well as with other domestic laws and international agreements, the law sets clear expectations for maritime activities within Vietnam's jurisdiction. Prohibiting actions that harm the marine environment reflects a proactive approach to conservation and underscores Vietnam's commitment to preserving its coastal and marine ecosystems for future generations. This legal framework likely serves as a vital tool in regulating maritime activities and promoting responsible environmental stewardship in Vietnam's waters. Vietnam's initiative to embark on a green port development project demonstrates its proactive approach toward sustainable maritime infrastructure. By setting a timeline for the implementation of green port standards, with voluntary adoption beginning in 2025 and formal integration by 2030, Vietnam shows its commitment to transitioning toward environmentally friendly port operations gradually.[88] It's commendable to see that many ports in Vietnam are proactively researching and incorporating Green Port criteria into their long-term goals. Large ports, often serving as key hubs of economic activity, play a crucial role in implementing governmental policies and driving sustainable practices within the maritime industry. By prioritizing the adoption of Green Port criteria, these ports not only demonstrate their commitment to environmental stewardship but also contribute significantly to national efforts to mitigate the environmental impact of maritime activities. Therefore, the author claims that:

Hypothesis 5: Regulations are positively related to the implementation of cold ironing.

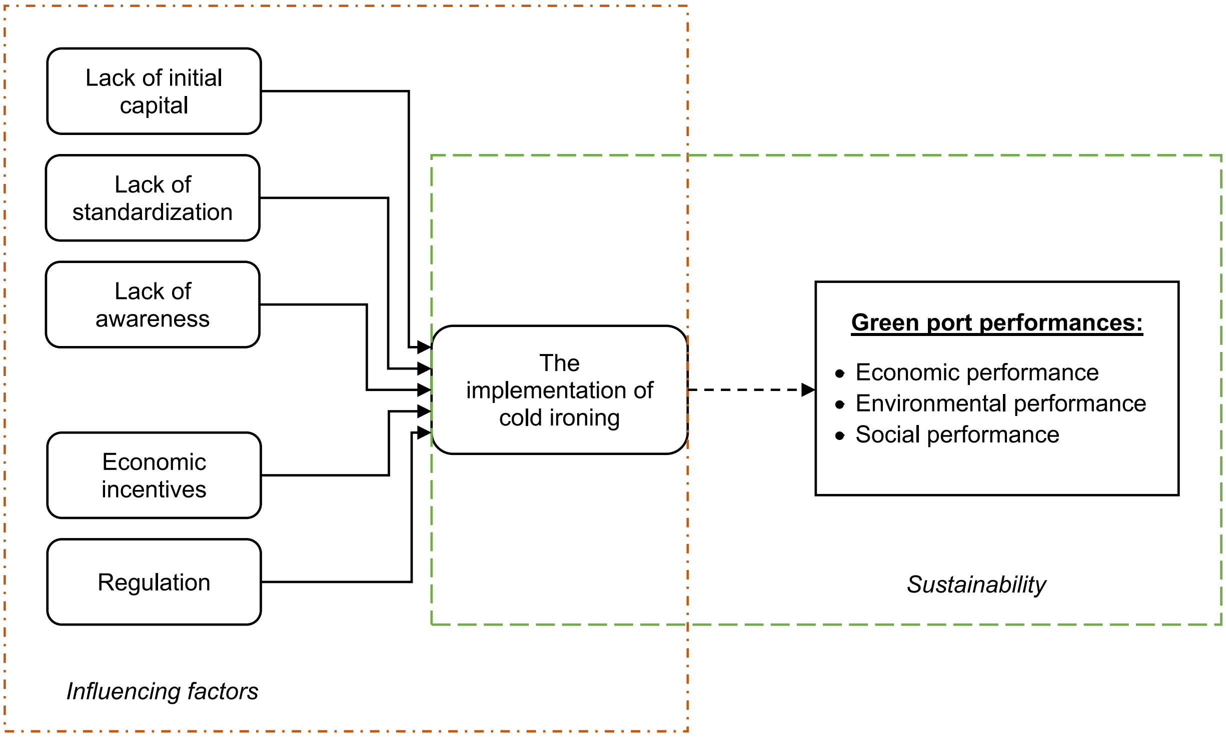

Figure 1. The proposed model.

Method

To achieve the research aims (Figure 1), the authors took the following measures. First, the authors collected data from participants at Vietnam's ten main ports. This study employed suitable data-gathering methods, such as email, to guarantee that the data was comprehensive and correct. Next, the data cleaning process consists of deleting invalid entries, addressing missing values, and guaranteeing data consistency. Third, the study employed SPSS 22.0 to assess the reliability, convergent validity, and discriminant validity of several measures. Finally, we utilized AMOS 22.0 to perform structural equation modeling (SEM) to examine the relationship between variables and research hypotheses.

Sampling and data collection

This research required a sample frame of ports that are now undergoing transformation into green ports, according to the Green Port Development Project of the Vietnamese government. Vietnam has a total of 34 seaports, including 13 large and 21 medium-sized and tiny ports. An appropriate sample frame for the survey was the 10 largest ports. As these ports transition to become green ports, they are putting sustainability standards into practice. Research on the implementation of cold ironing systems should focus on the 10 largest ports in Vietnam for the following reasons. First, large ports often have better financial resources and are able to recover investment capital faster due to the large volume of operations. Investing in a cold ironing system here can bring significant economic benefits through fuel savings and reduced long-term operating costs. Second, the successful implementation of cold ironing at large ports can create models for smaller ports to learn and apply in the future. This will help spread the environmental and economic benefits of cold ironing throughout Vietnam's port system. These ports are located throughout Vietnam's 3 distinct regions: the North, Central, and South. Participants in the research included department heads, members of management committees, port advisers, and senior officials. The participants, who participated voluntarily in order to progress science in general as well as Vietnam's Green Port Development Project, were informed of the objectives of the research. The participants were subsequently given emails with survey questions. Respondents indicated their agreement before answering the survey questions. The survey's questionnaire asks questions on the elements that led to the port's adoption of cold ironing based on the literature.

Participants were asked on the questionnaire's welcome page if their ports satisfied the criteria for a "Green port" or were working to build one. The survey on the variables that affected the adoption of cold ironing was given to participants who had selected "Yes" in response to the first question. A total of 360 emails were sent to potential participants from 10 different ports. As a result, 215 complete replies were received from the 10 ports, providing an effective response rate of 59.7%. Bachelor's degrees received the majority of replies (62.8%), followed by master's degrees (32.1%) and doctorate degrees (5.1%) (Table 1). Men made up 78.6% of the survey respondents, while women made up 21.4%. Senior leader (58.6%) is the most common job title, followed by division manager (26.5%) and president/vice president (14.9%). About 4.5% of people had been

Table 1. Characteristics of the participants.

	VARIABLE	CATEGORY	PERCENTAGE (%)	FREQUENCY
1	Degree of education	Bachelor	62.8	135
		Master	32.1	69
		Doctor	5.1	11
2	Gender	Male	21.4	46
		Female	78.6	169
3	Position	President/Vice president	14.9	32
		Division manager	26.5	57
		Senior leader	58.6	126
4	Working experience	Under 5 y	8.4	18
		6-10	18.1	39
		11-15	46.5	100
		16-20	16.7	36
		Above 20	10.2	22

working for between 11 and 15 years; these individuals were followed by 18.1% of those with between 6 and 10 years of experience, 16.7% of those with between 16 and 20 years, 10.2% of those with over 20 years, and 8.4% of those with <5 years.

Scales and measures

An approach known as a cross-sectional survey was used to collect the study's data. Research variables are measured via questions. The survey is divided into 3 main sections: (1) demographics; (2) cold ironing variables; and (3) the adoption process. The author used a 5-point Likert scale to assess both the constructs and observable items. In particular, 1 indicates strongly disagree; 2 indicates disagree; 3 indicates neutral; 4 indicates agree; and 5 indicates strongly agree. Participants will decide which point most accurately describes them. The operational definitions of each construct and reference are shown in Table 2. The results of factor analysis provided evidence of convergent and discriminant validity for constructs (Table 3).

Lack of initial capital. The scale of initial capital barriers was measured by 4 items.[3,89] This is an example of a statement: "A substantial sum of money is required to invest in cold ironing," or "A substantial sum of money is required to invest in onshore distribution."

Lack of standardization. We used 5 items to measure this scale.[73,74] This is an example of a statement: "Ships have different electrical requirements for voltage, some use 110 V, others 220 V," "Ships have different electrical requirements in terms of frequency, some at 50 Hz, some at 60 Hz," "Ships use different connection equipment and cables."

Lack of awareness. The awareness barriers scale was measured by 5 items.[71,78] This is an example of a statement: "Foreign capital invests in the port," "Foreign capital invests in cold ironing," and "Foreign capital is important."

Economic incentives. The variable of the incentive drivers was measured by 5 items.[83,89] This is an example of a statement: "Port has loans at low-interest rates," "Port may purchase electricity at a lower price," and "Port is decreased in business taxes."

Regulation. We used 5 items to measure the regulation driver scale.[3,89] This is an example of a statement: "Port requires ships to comply with the MARPOL conventions," "Port complies with IMO regulations," and "Port complies with national environmental protection laws."

The implementation of cold ironing. The dependent variable of this research is the process of cold ironing adoption. To measure this variable, we employed 5 items.[71,84] This is an example of a statement: "Port is consulted by experts in cold ironing," or "Port has a training program for employees on cold ironing."

Results

Principal Components Analysis

We first analyze the data using PCA with Promax rotation. A total of 62.7% of the variance is explained by all constructs. The 6-factor eigenvalue is 0.95, though, and the screen plot depicts a 6-factor structure. We then adjusted the number of observed components to 6 and ran the PCA once again. Standardization5 cross-loads on 2 constructions, according to the results. We

Table 2. The measure of variables.

NO	CONSTRUCT	ITEM	DESCRIPTION	AUTHOR
1	Lack of initial capital	Initialcapital1	A substantial sum of money is required to invest in cold ironing.	Innes and Monios[3]; Trellevik[89]
		Initialcapital2	A substantial sum of money is required to invest in onshore distribution.	
		Initialcapital3	A substantial sum of money is required to invest in grid connection.	
		Initialcapital4	The port has a lot of challenges getting investment money for cold ironing.	
2	Lack of standardization	Standardization1	Ships have different electrical requirements for voltage, some use 110 volts, others 220 volts.	Arduino et al[74]; Krämer and Czermański[73]
		Standardization2	Ships have different electrical requirements in terms of frequency, some at 50 Hz, and some at 60 Hz.	
		Standardization3	Ships use different connection equipment and cables.	
		Standardization4	The electricity usage of ships is different.	
		Standardization5	The operation and safety measures for cold ironing are different.	
3	Lack of awareness	Awareness1	Lack of information on the potential benefits of cold ironing	Radwan et al[71]; Diógenes et al[78]
		Awareness2	Lack of information on investment costs for cold ironing	
		Awareness3	Lack of understanding of technology	
		Awareness4	Lack of understanding of standardization	
		Awareness5	Lack of understanding of the market	
4	Economic incentives	Incentive1	Port has loans at low interest rates.	Tzannatos[83]; Trellevik[89]
		Incentive2	Port may purchase electricity at a lower price.	
		Incentive3	Port is decreased in business taxes.	
		Incentive4	Port can use traffic infrastructure at lower prices.	
		Incentive5	Port is awarded the Green Award.	
5	Regulation	Regulation1	Port requires ships to comply with the MARPOL conventions.	Innes and Monios[3]; Trellevik[89]
		Regulation2	Port complies with IMO regulations.	
		Regulation3	Port complies with national environmental protection laws.	
		Regulation4	Port applies sustainable port standards.	
		Regulation5	Port is developed according to the government's environmental orientation.	
6	The implementation of cold ironing	Coldironing1	Port plans to deploy cold ironing.	Radwan et al[71]; Williamsson et al[84]
		Coldironing2	Port survey and calculate investment amount for cold ironing system.	
		Coldironing3	Port is consulted by experts in cold ironing.	
		Coldironing4	Port has a training program for employees on cold ironing.	
		Coldironing5	Port introduces stakeholders to cold ironing technology.	

Table 3. Results of factor analysis.

STRUCTURE MATRIX						
	FACTOR					
	1	2	3	4	5	6
Coldironing1	0.929					
Coldironing3	0.893					
Coldironing2	0.759					
Coldironing4	0.748					
Coldironing5	0.715					
Regulation2		0.843				
Regulation4		0.785				
Regulation5		0.746				
Regulation1		0.714				
Regulation3		0.702				
Incentive4			0.884			
Incentive2			0.846			
Incentive3			0.676			
Incentive1			0.631			
Incentive5			0.614			
Initialcapital1				0.874		
Initialcapital2				0.873		
Initialcapital4				0.593		
Initialcapital3				0.578		
Standardization1					0.774	
Standardization3					0.772	
Standardization2					0.752	
Standardization4					0.657	
Awareness1						0.703
Awareness4						0.641
Awareness3						0.580
Awareness2						0.548
Awareness5						0.547

Abbreviations: Initialcapital, Lack of initial capital; Standardization, Lack of standardization; Awareness, Lack of awareness barriers; Incentive, Economic incentives; Regulation, Regulation; Coldironing, The implementation of cold ironing.

studied the wording of this item carefully and decided to delete it for additional data analysis. Following the removal of this item, all things are placed in the correct structures (Table 5). At 64.2%, all constructs explain the whole variance. After that, confirmatory factor analysis is performed.

Confirmatory factor analysis

AMOS 22.0 is used to perform Confirmatory Factor Analysis (CFA). The proposed 6-factor model accurately matched the data ($\chi2 = 400.506$, $df = 333$, $\chi2/df = 1.203$, $CFI = 0.98$, $TLI = 0.98$, $GFI = 0.90$, $IFI = 0.98$, $RMSEA = 0.029$). The value

Table 4. Result of the discriminant and convergent validity.

NO	CONSTRUCT	ITEM	FACTOR LOADING	VARIANCE EXPLAINED (%)	CRONBACH'S ALPHA	C.R	AVE
1	Lack of initial capital	Initialcapital1	0.876	65	0.84	0.84	0.54
		Initialcapital2	0.876				
		Initialcapital4	0.582				
		Initialcapital3	0.580				
2	Lack of standardization	Standardization1	0.706	56	0.85	0.84	0.55
		Standardization3	0.624				
		Standardization2	0.587				
		Standardization4	0.550				
3	Lack of awareness	Awareness1	0.769	66	0.82	0.83	0.53
		Awareness4	0.768				
		Awareness3	0.747				
		Awareness2	0.664				
		Awareness5	0.623				
4	Economic incentives	Incentive4	0.772	60	0.87	0.86	0.53
		Incentive2	0.719				
		Incentive3	0.692				
		Incentive1	0.681				
		Incentive5	0.676				
5	Regulation	Regulation2	0.810	66	0.88	0.87	0.54
		Regulation4	0.796				
		Regulation5	0.782				
		Regulation1	0.742				
		Regulation3	0.663				
6	The implementation of cold ironing	Coldironing1	0.944	72	0.89	0.88	0.58
		Coldironing3	0.891				
		Coldironing2	0.741				
		Coldironing4	0.736				
		Coldironing5	0.711				

Abbreviations: Initialcapital, Lack of initial capital; Standardization, Lack of standardization; Awareness, Lack of awareness barriers; Incentive, Economic incentives; Regulation, Regulation; Coldironing, The implementation of cold ironing; AVE, average variance extracted; CR, composite reliability.

of $\chi 2/df$ should be less than 3, a suitable match for RMSEA is no greater than 0.08, and the cutoff value of CFI and TLI is 0.90 or higher, according to prior research.[90] Therefore, the fit indices for the 6-factor model proposed for this study are regarded as adequate.

Cronbach's alpha and composite reliability (CR) are the 2 metrics used to evaluate the variables' consistency and dependability. Hair et al[91] state that 2 values have been used instead of only one. According to Hair et al[92], Cronbach's alpha and CR values need to be >.7. Table 4 shows that all of the CR values were higher than the cutoff value of 0.7 for the following factors: regulation drivers (0.87), incentive drivers (0.86), initial capital barriers (0.84), standardization barriers (0.84), awareness barriers (0.83), and the adoption of the cold ironing process (0.88). Additionally, the results from Table 4 also presented that Cronbach's alpha of all factors is larger than .7.

Fornell and Larcker[93] discovered that when the value of average variance extracted (AVE) is >0.5, it fits the conditions. According to the findings, the AVE values of regulation drivers, incentive drivers, environmental drivers, macroeconomic drivers, foreign capital drivers, and the process of cold-ironing adoption are, respectively, 0.54, 0.53, 0.54, 0.55, 0.53, and 0.58. These items' typical factor loadings exceed 0.50. (range from 0.55 to 0.94). There are >50% of explained variances for each construct.[94] This demonstrates that the constructs reach convergent validity.

Common method variance

Tehseen et al[95] defined common method variance (CMV) as the systematic error variation that develops when variables are assessed using the same source or technique.[96] As a result, the systematic error variance may be biased. Because respondents consistently answered all survey items, the anticipated connection between variables may be overstated or underestimated.[95,96]

We used and looked at CMV prevention strategies in this study. To stop respondents from figuring out which attributes were associated with which factors, we first employed a series of mixed questions.[97] Furthermore, we employed popular statistical techniques, such as partial removal of the general construct and Harman's single-factor test, to assess the CMV in our investigation.[95] Six distinct variables emerged from the calculated principal component analysis (PCA) results, accounting for 64.2% of the total variance (Table 5). The first unrotated component accounted for just 18.1% of the data variance (less than 50%). The first component does not account for the majority of the variance, and no single factor emerges. As a consequence, data analysis revealed that CMV was absent from this study.

Hypotheses testing

Structural equation modeling (SEM) was used to investigate the connections between dimensions and run path analysis. The hypothesis was tested by assessing the direction of exogenous factors on endogenous variables using standardized coefficients. The Structural Equation Model (SEM) is constructed according to the following steps:

Model specification. This initial step involves defining the model based on theoretical considerations. It includes the structural model and measurement model. The structural model specifies the relationships between lack of initial capital, lack of standardization, lack of awareness, economic incentives, regulation, and the cold ironing implementation. The measurement model defines how latent variables are measured by observed variables (indicators).

Model identification. Before estimating the model, it must be identified, meaning there must be enough information to estimate the parameters. This involves ensuring there are sufficient data points (observations) relative to the number of parameters to be estimated.

Model estimation. The parameters of the model are estimated using statistical methods. These methods provide estimates for path coefficients, factor loadings, variances, and covariances of the latent variables

Model testing and evaluation. This step assesses how well the model fits the data. Several indices and tests are used: Chi-Square, Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), and Root Mean Square Error of Approximation (RMSEA).

Hypothesis testing. The core of hypothesis testing in SEM involves examining the path coefficients and other estimated parameters.

The results of the SEM test indicated that the goodness-of-fit indices of the theoretical model ($\chi2 = 400.506$, $df = 333$, $\chi2/df = 1.203$, $CFI = 0.98$, $TLI = 0.98$, $GFI = 0.90$, $IFI = 0.98$, $RMSEA = 0.029$) were acceptable (Figure 2).

Table 6 displays the outcomes of our hypothesis testing. Our results corroborate Hypotheses 1 by showing that early hurdles negatively impact the adoption process of cold ironing ($\beta = -.34$, $P < .01$). Furthermore, our research revealed a negative correlation ($\beta = -.26$, $P < .05$) between standardizing hurdles and the adoption process of cold ironing. As a result, Hypothesis 2 was approved. According to our findings, the process of cold ironing adoption was favorably correlated with incentive and regulation drivers ($\beta = .13$, $P < .01$ and $\beta = .44$, $P < .001$, respectively). Thus, Hypotheses 4 and 5 were supported. Contrary to our predictions, Hypothesis 3 was rejected. Awareness barriers have no impact on the process of cold ironing adoption ($\beta = .09$, $P > .05$).

Discussion

Environmental sustainability has emerged as one of the major pillars on the agenda of many marine ports as a result of the issues with climate change as well as the expanding requirements for the logistics and transportation industry. The numerous sources and types of port-related emissions, including those from seagoing ships, heavy-duty vehicles, and cargo-handling equipment, have a substantial negative influence on the environment.[98] In addition, the port community is made up of a variety of actors and stakeholders with varying viewpoints and objectives toward environmental sustainability. As a result, green ports are created as a means of achieving this objective. It is possible to describe sustainable port development as commercial strategies and operations that fulfill the present and future demands of ports and their stakeholders while safeguarding and sustaining human and natural resources.[99] Denktas-Sakar and Karatas-Cetin[99] said that the goal of achieving port sustainability should be pursued both inside an organization and in partnership with port partners across key supply chain members. They must create technical innovation to meet a global environmental goal while also increasing their level of competitiveness.

Table 5. Total variance results explained.

TOTAL VARIANCE EXPLAINED							
FACTOR	INITIAL EIGENVALUES			EXTRACTION SUMS OF SQUARED LOADINGS			ROTATION SUMS OF SQUARED LOADINGS
	TOTAL	% OF VARIANCE	CUMULATIVE %	TOTAL	% OF VARIANCE	CUMULATIVE %	TOTAL
1	5.081	18.147	18.147	4.723	16.868	16.868	4.096
2	3.603	12.866	31.013	3.192	11.399	28.268	3.047
3	2.805	10.019	41.033	2.370	8.466	36.734	3.646
4	2.536	9.058	50.090	2.080	7.427	44.161	2.337
5	2.210	7.892	57.982	1.692	6.043	50.204	2.309
6	1.737	6.203	64.185	1.401	5.002	55.206	1.961
7	0.936	3.342	67.527				
8	0.847	3.024	70.551				
9	0.740	2.644	73.195				
10	0.709	2.530	75.726				
11	0.628	2.242	77.968				
12	0.588	2.101	80.069				
13	0.553	1.974	82.043				
14	0.519	1.853	83.896				
15	0.495	1.768	85.665				
16	0.470	1.678	87.342				
17	0.458	1.636	88.978				
18	0.421	1.503	90.482				
19	0.390	1.393	91.874				
20	0.387	1.381	93.255				
21	0.341	1.218	94.473				
22	0.335	1.196	95.669				
23	0.306	1.092	96.761				
24	0.255	0.912	97.673				
25	0.220	0.786	98.459				
26	0.194	0.693	99.152				
27	0.165	0.589	99.741				
28	0.072	0.259	100.000				

For the decrease of environmental pollution in port regions, cold ironing is one potential answer. As documented for the ports of Los Angeles (US), Oslo (Norway), Aberdeen (Scotland), Copenhagen (Denmark), and Kaohsiung (Taiwan), previous studies have shown the advantages of cold ironing from both an environmental and an economic perspective.[3,20,39,48,49] Furthermore, cold ironing is a practical method for lowering environmental pollution, which eventually lowers the number of people dying from air pollution-related diseases like asthma, lung cancer, heart attacks, and chest discomfort.[10,56,57] Additionally, cold ironing saves money on the societal costs associated with treating illnesses brought on by air pollution from ships. The expense of ship emissions has been assessed by several studies. When considered as a way to cut

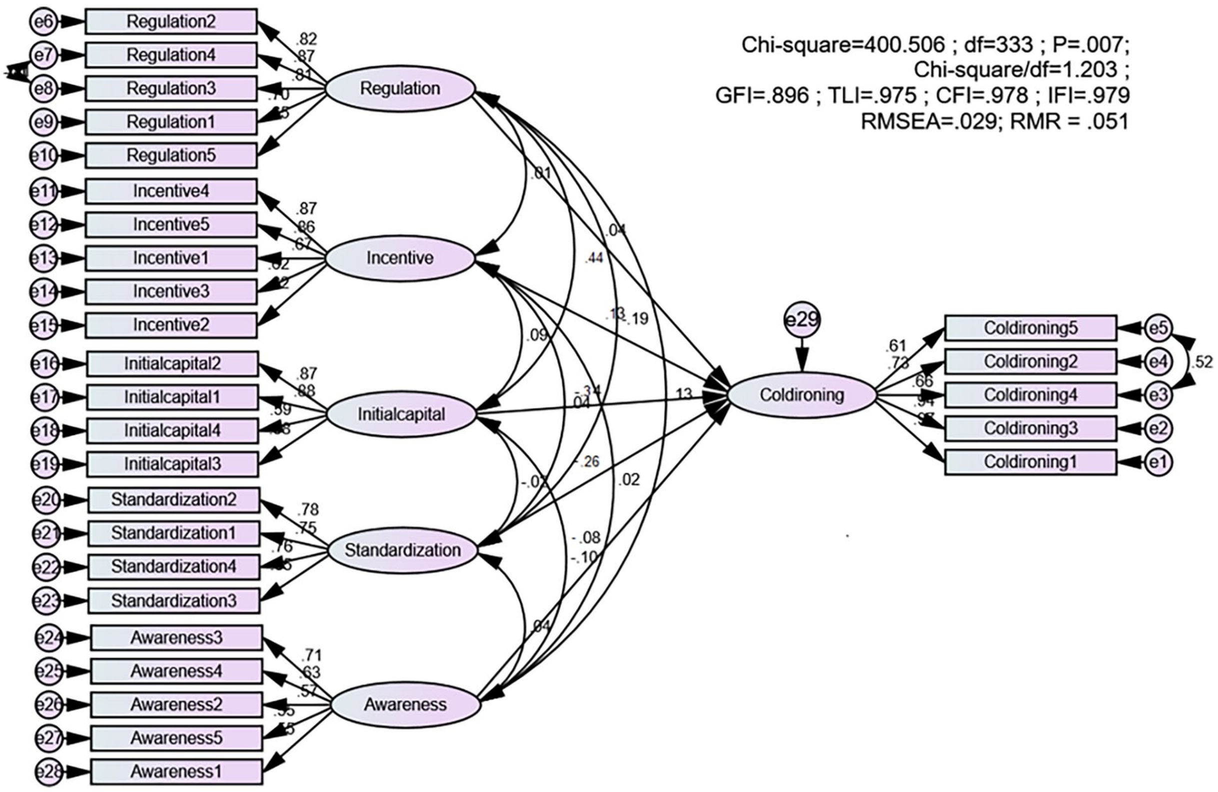

Figure 2. The standardized path coefficient of the suggested model.

Table 6. Results of hypothesis testing.

HYPOTHESIS NO.	INDEPENDENT VARIABLE	DEPENDENT VARIABLE	BETA	*P*-VALUE	SUPPORT HYPOTHESIS
1	Initial capital	Cold ironing	−.343	.006	Yes
2	Standardization	Cold ironing	−.262	.012	Yes
3	Awareness	Cold ironing	−.085	.117	No
4	Incentives	Cold ironing	.132	.004	Yes
5	Regulation	Cold ironing	.435	***	Yes

Abbreviations: Initial capital, Lack of initial capital; Standardization, Lack of standardization; Awareness, Lack of awareness barriers; Incentives, Economic incentives; Regulation, Regulation; Coldironing, The implementation of cold ironing.
***$P < .001$.

back on external costs to society as a whole and port cities, in particular, cold ironing offers a number of advantages. Studying the factors that influence the application of cold ironing is crucial for the widespread adoption of this technology in ports in developing nations. This study conducted a survey of 215 participants from the 10 main ports in Vietnam, and acquired the subsequent significant findings:

- Lack of initial capital has a negative impact on the adoption of cold ironing.
- Lack of standardization hinders the successful implementation of cold ironing.
- Inventive drivers have a beneficial influence on the implementation of cold ironing.
- Regulatory drivers have a beneficial effect on the adoption of cold ironing.

Theoretical implications

First, our findings demonstrate that the adoption of cold ironing is negatively impacted by initial capital obstacles, which has complemented previous research results.[71,73,84] Previous studies indicate that investing in a cold ironing system indeed requires a significant financial commitment. The overall may range from a few million to tens of millions of USD, depending on the size of the port and the number of ships requiring assistance. Williamsson et al[84] explained that costly investments are a significant barrier to the adoption of cold ironing because they are likely required for numerous types of hardware. The ports of Aberdeen and Copenhagen, for example, were expected to incur investment costs of £6.6 million and €37 million, respectively.[3,20] This study deepens our awareness of the challenges associated with cold ironing. If port authorities intend to go in a sustainable direction, it helps to be proactive in building up a source of money. The government may use our findings to help promote the implementation of sustainability criteria at ports. In order to make the business model more attractive, it is crucial to develop ways to lower investments or connect investments to values.[84]

Second, our findings indicate that the absence of standardization is impeding the adoption of cold ironing in ports, which extends the results of previous studies.[10,71,73,74] This finding is a significant contribution to the existing research on obstacles to the adoption of cold ironing in developing nations. Early on, it was recognized that the absence of standards for linking shore to ship was a difficulty for the expansion of cold ironing, and it was proposed that a wide alliance of parties, including shipbuilders and port officials, would promote the development of practical, cost-effective solutions.[100] According to our research, increasing the standardization of electricity's voltage and frequency between shore and ship will encourage the reduction of local pollutants at ports through cold ironing. Additionally, attention should be paid to the standardization of cables and connections. The complexity, expense, and difficulty of implementing cold ironing toward sustainability will be reduced by more standardization.[84]

Furthermore, our findings showed that incentive drivers have a positive impact on the adoption of cold ironing, supporting earlier qualitative research.[78,80,83,84,87] The results of our research have enhanced the existing literature on the factors that affect the implementation of cold ironing in developing countries, where there is typically a shortage of funds and technology. When financial incentives are used as effectively as possible, projects, especially those with high initial investment costs like cold ironing, can develop more quickly and be commercially feasible. The difficulties in implementing financial incentives for cold ironing are primarily caused by the long and complex, complicated, and bureaucratic procedures needed to gather the required paperwork in contrast to the short application deadlines, followed by the lengthy period needed to evaluate the requests and release the incentives.

Finally, our findings indicated that regulation drivers have a positive impact on the adoption of cold ironing, which is consistent with other studies.[3,8] Regulations are essential for driving the adoption of this technology in both developed and developing countries, which makes a substantial contribution to the theoretical foundation. The reason why cold ironing is not widely used in some nations is due to weak national legislation on issues like air pollution.[39] Regulation in the shipping sector must be strategically targeted, taking into account specific factors such as the time vessels spend in port and their respective pollution levels. This tailored approach ensures that regulations are both effective and efficient in addressing environmental concerns. Despite the absence of regulatory support hampering the growth of cold ironing (the process of providing shore-side electrical power to a ship at berth while its main and auxiliary engines are turned off), there are 3 types of policy instruments from the energy sector that can be applied to promote cold ironing.[84,101] First, regulatory instruments involve direct regulations that mandate the use of cold ironing in ports. For instance, governments can set strict emissions standards that require ships to connect to shore power if they exceed certain pollution thresholds. This type of regulation can compel shipping companies to adopt cold ironing to comply with environmental laws. Second, eonomic instruments include financial incentives and penalties designed to encourage the adoption of cold ironing. Subsidies, tax breaks, or grants can be provided to ports and shipping companies to offset the initial costs of installing cold ironing infrastructure. Conversely, imposing higher port fees or pollution taxes on ships that do not use shore power can economically motivate compliance. Finally, informational instruments focus on spreading awareness and providing information about the benefits and technical aspects of cold ironing. Government agencies and industry groups can launch educational campaigns, offer technical training, and create best practice guidelines. This helps in building knowledge and acceptance among stakeholders, facilitating the smoother implementation of cold ironing technologies. By utilizing these policy instruments, regulators can more effectively support the adoption of cold ironing, thus reducing port-related emissions and contributing to overall environmental sustainability in the maritime sector.

Managerial and practical implications

Humans are significantly impacted by the consequences of climate change, which is a result of human economic activity. Action plans are actively developed by nations to lessen their adverse environmental consequences and build sustainable economies. A Green port model has been developed by nations with sustainable requirements for the marine industry, including reducing noise, air pollution, and water pollution; using alternative energy sources; and raising environmental awareness. One important strategy for reducing regional emissions at the port is cold ironing. The study's conclusions have a few managerial and practical implications.

Initially, the government should establish a set of specific regulations and policies to encourage the implementation of cool ironing systems at ports. If the infrastructure is accessible, the government establishes mandatory regulations that require ships docking at terminals to utilize cold ironing.[34] These regulations may be predominantly applicable to ships with elevated emissions, including container ships, cruise ships, and cargo ships. The government should establish a precise timeline for the implementation of this regulation, such as mandating that all newly constructed vessels be equipped with cold ironing capabilities from a specific date.[102] Furthermore, the International Maritime Organization (IMO) has the authority to establish mandatory standards for cold laundering in conventions like MARPOL (Regulations for the Prevention of Pollution from Ships). These regulations will contribute to the reduction of environmental pollution and the protection of public health by establishing a legal framework that encourages ports and shipping businesses to invest in and utilize cold ironing systems.

Secondly, technical standardization is a critical factor in the promotion of the use of cold ironing systems at ports. Therefore, it is imperative that the government encourage the implementation of technical standardization. For instance, the IEC/ISO/IEEE 80005 series of standards is one of the most critical standards for cold ironing systems at ports.[103] Three of the most significant international standards organizations—IEC (International Electrotechnical Commission), ISO (International Organization for Standardization), and IEEE (Institute of Electrical and Electronics Engineers)—collaborated to create this collection of standards. It guarantees the HVSC system's precise specifications, including the voltage, frequency, current, and power quality requirements. Furthermore, port associations must also reach an agreement regarding the standardization of interfaces and connections. This guarantees that the devices and terminals that connect ships and harbors adhere to international standards, thereby guaranteeing safety and compatibility during the connection process.

The government should then implement a variety of incentives that are specifically designed to address financial, regulatory, operational, and educational barriers in order to encourage the adoption of cold ironing systems at ports. Financial assistance should be provided by the government to maritime companies and terminals for the initial installation and upgrading of cold ironing infrastructure. As an additional measure, the government should implement low-interest loan programs to mitigate the initial capital expenditures for shipping companies and terminals that are investing in cold ironing systems.[104] Through a series of tax policies and incentives, the government has the ability to lower taxes for locations that invest in cold pressing systems. Furthermore, the government should eliminate or reduce import tariffs on equipment and technology that are associated with cold ironing, such as shore power systems, engineering equipment, and components.

Lastly, in order to guarantee the success of this project, port managers should proactively pursue initial capital to invest in a cool pressing system. For instance, financial institutions or commercial banks may provide loans to ports. Detailed and feasible financial planning will assist ports in persuading these organizations to provide the requisite loans. In order to attract investors who are interested in social and environmental responsibility, ports may issue green bonds to raise capital for environmentally favorable and sustainable initiatives.[105] Additionally, the government has the option of offering support funds or subsidy programs for environmentally responsible initiatives, such as cold ironing systems, in order to mitigate the initial investment costs. Alternatively, the government may implement preferential loan programs with low or no interest rates for renewable energy and environmental improvement initiatives in order to address the initial capital barriers associated with the implementation of cold ironing.

Limitations and future research direction

Despite its many contributions and implications, this study still has severe limitations. First of all, just 10 of Vietnam's major container ports were polled for this study, which did not accurately reflect how generalizable the results were. Therefore, we suggest that future research concentrate on submitting to additional ports. In addition, due to their high levels of pollution, dry ports must also be examined. The second drawback is that this study has not investigated the quality of local electricity supply. The stability and quality of the electricity supply are crucial for the successful operation of cold ironing systems. Fluctuations in voltage or frequency can damage sensitive shipboard electronics and systems. Ports in regions with unstable power supplies might need to invest in additional equipment to ensure consistent and reliable power delivery. Indeed, the quality of the electricity supply is a crucial factor that can significantly impact the implementation of cold ironing at ports. Future studies could explore various aspects of this relationship to provide a comprehensive understanding and actionable insights. Next, the study did not investigate the economic, environmental, or social impacts of cold ironing; instead, it concentrated solely on identifying the factors that influence and hinder the adoption of cold ironing. Future research may thus examine how cold ironing affects the 3 aspects of sustainability. Another weakness of this study is the respondents' self-evaluation of the concept of "green port". As a result, future research should make it clear to survey participants that green ports must be identified and rated. As a consequence, they may have a better perception of the green port and may appropriately evaluate the cold ironing. Furthermore, offering a clear concept and established assessment criteria for green ports not only helps employees grasp environmental goals but also motivates them to actively participate in workplace environmental protection activities.

Author contribution

Methodology: Son-Tung Le; Software: Son-Tung Le; Formal analysis: Son-Tung Le; Writing – original draft: Son-Tung Le; Writing – review & editing: Son-Tung Le; Supervision: Son-Tung Le.

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