# A Literature Review on Container Yard Location Planning to Support Sustainable Shipping

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**Abstract.** The shipping industry plays a vital role in global trade but also faces major challenges regarding its environmental impact. This research aims to explore solutions to reduce the shipping industry's environmental impact, focusing on three main aspects: sustainable container stacking site planning, implementation of the green port concept, and use of environmentally friendly alternative fuels. Through the literature review method, this research analyzed various academic sources related to sustainable shipping. The results show that the implementation of the dry port concept with the Center of Gravity method is effective in optimizing container stacking locations, reducing distribution distances and emissions. The implementation of green technologies such as electrification of loading and unloading equipment and smart traffic management at the port contribute significantly to emission reduction. The use of alternative fuels such as hydrogen and ammonia shows great potential in creating cleaner port operations, although it still faces challenges in implementation. In conclusion, the integration of these strategies in port planning and operations can substantially reduce the shipping industry's environmental impact, support long-term sustainability and improve operational efficiency. Further research is needed to assess the effectiveness of these models in different geographic and economic contexts, as well as potential synergies with other sustainability initiatives in the maritime sec- tor.

**Keywords:** Kata Kunci Pertama, Kata Kunci Kedua, Kata Kunci Ketiga. Dituliskan dalam Bahasa Inggris

## 1. Introduction

Shipping has long been the lifeblood of global trade, playing a crucial role in facilitating the exchange of goods and commodities around the world. Not only is the sector a key driver of the global economy, but it is also a vital component of international supply chains. However, despite its pivotal role, the shipping industry also faces major challenges regarding its impact on the environment [4]. Maritime ecosystems are inseparable from sustainable life on earth, and maritime and other aquatic areas, including coasts, play an important role in supporting and connecting various ecosystem functions, human health, and several key economic sectors. Rusastra (2020) emphasized the importance of maintaining a balance between economic utilization and preservation of


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the maritime environment to ensure the sustainability of not only the shipping sector, but also life on earth as a whole.

While providing substantial economic benefits, the shipping industry has also faced strong criticism for its significant environmental impacts. The main negative im- pacts caused by the shipping industry include Large ships used in shipping are a signif- icant source of carbon emissions. The International Maritime Organization (IMO) esti- mates that international shipping accounts for about 2.2% of total global carbon dioxide emissions. This figure is expected to increase as global trade grows without significant mitigation measures [5]. Oil spills, waste disposal and fuel leaks from ships can pollute marine ecosystems. This pollution not only impacts marine life, but can also affect the food chain and ultimately human health. Shipping can disrupt the natural habitat of marine life. This includes the impact of sound on marine mammals, the risk of colli- sions with marine animals, and the introduction of alien species through ship ballast water that can disrupt the balance of local ecosystems [7]. In addition to carbon emis- sions, ships also produce other air pollutants such as sulfur oxides (SOx), nitrogen ox- ides (NOx) and fine particulate matter. These pollutants can negatively impact air qual- ity in coastal areas and ports, and contribute to public health issues [5]. The shipping industry's reliance on fossil fuels, especially heavy fuel oil, not only contributes to greenhouse gas emissions but also faces long-term sustainability challenges given the finite nature of fossil resources [3].

Facing pressure from the global community to reduce these negative impacts, the shipping industry is now increasingly paying attention to sustainability in its oper- ations. Initiatives to reduce environmental impacts have emerged from various parties, including international regulations, technological innovations, and changes in opera- tional practices [4]. One important aspect of sustainable shipping that has received par- ticular attention is container yard site planning. The container yard is a critical point in the global supply chain. Here, goods are consolidated, processed, and distributed. Choosing the right location for a container yard has major implications on several as- pects such as, A strategic location can increase speed and efficiency in the loading, unloading and distribution process. This not only optimizes time, but can also reduce fuel consumption and emissions resulting from the movement of vehicles and equip- ment [1]. Proper site selection can reduce overall transportation and logistics costs. This includes fuel, labor, and infrastructure maintenance costs. In addition, good planning can help minimize disturbance to local ecosystems and reduce the potential for pollu- tion [2].

Mistakes in site selection can lead to an increase in excessive fuel use, which in turn will increase emissions. Munim et al. (2023) emphasized that traditional marine fuel combustion, especially heavy fuel oil. Which produces various types of harmful emissions, including Carbon Dioxide (CO), Sulfur Oxides ($SO_x$), Nitrogen Oxides ($NO_x$), Carbon Monoxide (CO), Hydrocarbons, Particulates. All of these emissions have significant impacts on the environment and human health, especially workers in the marine logistics sector and communities living around port areas and shipping lanes [5].

In this context, this research aims to explore solutions that can be implemented to reduce the environmental impact of the shipping industry, focusing on three main aspects: [a] Sustainable container stacking site planning, [b] Implementation of the green port concept, [c] Use of environmentally friendly alternative fuels. By examining these three aspects, this research seeks to contribute to efforts to create a more sustainable and environmentally friendly shipping industry [4].

## 2. Method

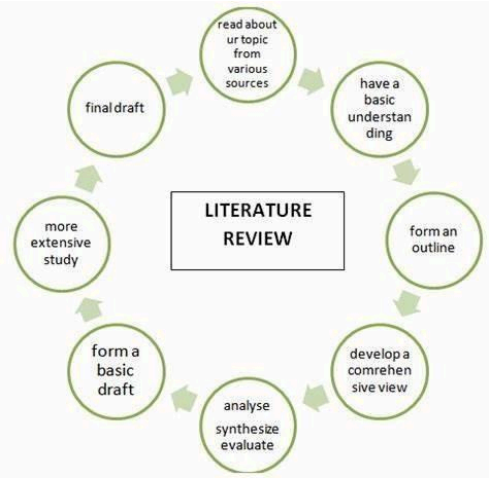


Figure. 1 The flow of literature review method

This type of research is literature review, which is a series of studies with research methods whose research objects are explored through various library information. Research using the literature review method is research that examines and crit- ically reviews knowledge, ideas or findings in academic-oriented literature, and formu- lates its theoretical and methodological contributions to certain topics. The focus of this research is to find various theories, laws, principles or ideas to analyze and solve the formulated research questions. The nature of this research is descriptive analysis, which is a regular description of the data that has been obtained, then given an understanding and explanation with the aim of being well understood by the reader. In the context of this research, a literature review was conducted by collecting and analyzing various academic sources relevant to the topic of sustainable shipping, including scientific journals, textbooks, industry reports, and publications of international organizations such as IMO (International Maritime Organization) [4] (Figure 1). The data col- lection process involved a systematic search using relevant keywords in various aca- demic databases such as Scopus, Web of Science, and Google Scholar. Data analysis was conducted through several stages including Identification of key themes in the

collected literature, Categorization of findings based on the three main focuses of the study: dry port location, green port concept, and alternative fuels, Synthesis of information to identify trends, gaps, and further research opportunities, Critical evaluation of the methodology and findings of the analyzed studies [7].

## 3. Result and Discussion

### 2.1. Dry port siting to support sustainable shipping

Figure. 2 Container Yard

The dry port concept is a logistics facility located on land and functions the same as a port, namely as a place for loading and unloading transportation, stacking / warehousing and cargo documentation (Figure 2). Dry port has a distance that is not too far from the sea port. Planning the location of this container storage is expected to reduce emissions during operational activities. In planning the location, the location of ship loading and unloading activities should be close to the container stacking location. In addition, to create sustainable shipping, it can use electrical energy in the use of all tools that can cause emissions. The method used in determining the location of the dry port is the Center of Gravity method. This method will place the selected location close to the location of the highest source of supply, thus minimizing the distribution distance. Ac- cording to the following is the formula for determining the location of the COG method [1]:

$$\mathbf{X} = \frac{\sum_i x_i d_i}{\sum_i d_i} \qquad \mathbf{Y} = \frac{\sum_i x_i d_i}{\sum_i d_i}$$

Where:

(X, Y) = Point coordinates
($X Y_{i,\,i}$) = Charge origin coordinates
$d_i$ = Load volume

With the above formula, the coordinates of the closest location suitable for an environmentally friendly container stacking location can be found. Various optimization methods have been used in container yard location planning. One method that is often used is the Center of Gravity (COG). According to Murdjito & Christino Boyke

(2015), the COG method is effective in determining the optimal location by considering the volume of cargo and the coordinates of the cargo origin [1]. The COG formula allows the determination of coordinate points that minimize distribution distance, which in turn can reduce fuel consumption and emissions. In addition to COG, Multi-Criteria Decision Making (MCDM) methods are also widely used. Research by Zhang et al. (2022) showed that the MCDM approach can integrate various factors such as accessibility, land cost, environmental impact, and economic growth potential in determining the location of dry ports. This method enables more comprehensive decision-making by considering sustainability aspects [2].

### 1.2. Emission reduction considerations in planning a container stacking yard based on the green port concept

In planning the container stacking yard, it is necessary to consider the reduction of gas emissions based on the green port concept. the application of the method of sub- stituting onshore electrical energy to anchored ships to reduce exhaust emissions and preserve the environment. Research results showed that the reduction of NOx, VOC, and PM emissions reached 90%, 87%, and 82% nominally, which are significant fig- ures. The integration of the national grid system with the electrical energy demand at the docks also increases the load factor of the power system. In addition, this method can reduce the impact of harmful gas emissions and increase the added value of the port [6]. Another study discussed the use of the STS system to reduce exhaust emissions from ships at Tanjung Priuk Port. Simulation results show that the use of STS can sig- nificantly reduce NOx, SOx, VOC, and PM emissions, with a reduction in NOx emis- sions of up to 97%. This shows the great potential of using STS in reducing the impact of air pollution from ships in the port [6].

Emission reductions in container yard planning include, Electrification of loading and unloading equipment. This electrification means replacing the fuel for loading and unloading equipment with an electric version. Loading and unloading equipment when using diesel fuel can cause gas emissions and is certainly very dangerous for workers. To reduce gas emissions in the port, design an efficient layout to minimize vehicle mileage. If the distance between the container yard and the dock is close, the gas emissions in the port will definitely be reduced as well [6]. An efficient layout design can be seen in Figure 3.

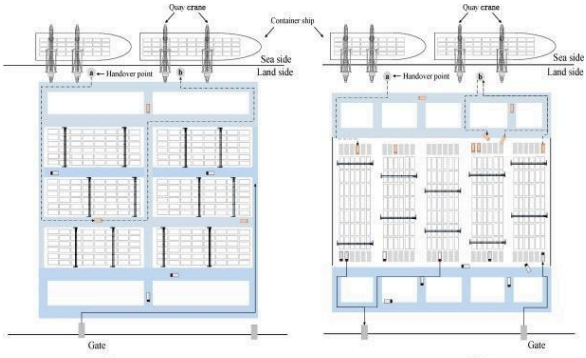


Figure. 3 Design of an efficient container yard layout

In addition, planning a container yard requires intelligent traffic management such as the use of sensors and cameras for real-time traffic monitoring [2].

### 1.3. The potential of hydrogen and ammonia fuels to support sustainable container yard planning

Hydrogen and ammonia fuels have significant potential in supporting sustainable container yard planning, offering innovative solutions to reduce the environmental impact of port operations. Both fuels promise to drastically reduce greenhouse gas emissions, with hydrogen only producing water as a by-product when used in fuel cells, while ammonia produces no direct CO2 emissions when burned or used in energy sys- tems. This paves the way for cleaner port operations and is in line with global goals to reduce the carbon footprint of the maritime industry [3].

The flexibility of using hydrogen and ammonia is one of their main advantages. Hydrogen can be applied to various types of vehicles and loading and unloading equip- ment, ranging from forklifts to heavy trucks, while ammonia is suitable for large-scale internal combustion engines and turbines. The high energy density of hydrogen allows for longer operation without the need for frequent refilling, while ammonia is easier to store and distribute in liquid form at room temperature. This combination of character- istics allows ports to design energy systems that are efficient and adaptable to various operational needs [3].

The integration of hydrogen and ammonia with renewable energy sources opens up the opportunity to create a truly sustainable energy cycle at the stacking yard. Both fuels can be produced using electricity from renewable sources such as wind or solar, creating what is known as "green hydrogen" and "green ammonia". This approach not only reduces dependence on fossil fuels, but also improves port energy security by en- abling local energy production. This can protect port operations from fluctuations in global energy prices and ensure a stable energy supply [5].

The synergy between the use of hydrogen and ammonia in ports and trends in the shipping industry is also very promising. As more and more ships switch to these alternative fuels, ports that have adopted similar technologies will be in an advantageous position. They can provide bunkering services for new generation ships and integrate clean energy systems between ships and land facilities through improved cold ironing technology. This not only improves port competitiveness but also contributes to the decarbonization of the entire maritime logistics chain [5].

The adoption of hydrogen and ammonia also has the potential to drive green economic development around the port. Implementation of these technologies will cre- ate a need for a skilled clean energy workforce, from technicians to specialist engineers. Ports can become centers of innovation, attracting investment in research and develop- ment of related technologies. This not only increases the economic value of the port but also contributes to a broader energy transition in society [4]

While the potential is great, the implementation of hydrogen and ammonia in container stacking yard planning also faces challenges. High initial infrastructure costs, the need for strict safety standards, and the need for mature supply chain development are some of the barriers that need to be overcome. However, with the right policy sup- port, strategic investments, and collaboration between various stakeholders, these chal- lenges can be overcome gradually [3].

In the long term, the adoption of hydrogen and ammonia as the primary fuels in container stacking yards could be key in creating truly sustainable ports. This will put ports in a strong position to meet increasingly stringent environmental regulations, at- tract business partners committed to sustainability, and contribute significantly to global efforts to reduce the impact of climate change. As such, investment in this technology is not just about environmental compliance, but also about ensuring the competitiveness and relevance of ports in a future that is increasingly focused on sustainability [4].

## 4. Conclusion

Based on the formulation of the article, the results and discussion reviewed and discussed in this article, it can be concluded that strategic container yard location plan- ning, especially dry port implementation, has a crucial role in reducing emissions and supporting sustainable shipping. The use of the Center of Gravity method in determin- ing dry port locations has proven effective in optimizing distribution distances, which directly impacts the reduction of fuel consumption and emissions. The concept of dry ports as inland logistics facilities that function like ports shows great potential in im- proving operational efficiency and reducing environmental impacts. The dry port's lo- cation not too far from the sea port allows for a significant reduction in vehicle and equipment movement, which in turn reduces emissions. The integration of green tech- nologies, such as the use of electrical energy for operational equipment at the container yard, is an important step in creating a sustainable shipping system. Proper site planning not only has an impact on reducing emissions, but also has the potential to lower overall transportation and logistics costs, including fuel, labor, and infrastructure maintenance costs. Strategic container yard site selection can help minimize disruption to local eco- systems and reduce potential pollution, in line with sustainable shipping principles.

For further research, it is recommended to conduct a comparative study on the effectiveness of various container yard site planning models across different geograph- ical and economic contexts. Explore the integration of smart technologies and inte- grated management systems in dry port operations to improve efficiency and sustaina- bility. Examine the long-term impact of dry port implementation on trade patterns and regional economic development. Analyze potential synergies between container yard site planning and other green port initiatives to create a more comprehensive and sus- tainable logistics system. Evaluate policy and regulatory aspects that may support or hinder the development and optimization of container yard sites in the context of sus- tainable shipping.

The dry port concept is emerging as a potential solution in supporting sustainable shipping. According to Roso et al. (2019), the implementation of dry ports can reduce congestion at major ports, lower emissions from land transportation, and improve overall supply chain efficiency. Their research shows that optimized dry port locations can reduce truck miles by up to 30%, which directly correlates with reduced CO2 emis- sions. Case studies in various countries demonstrate the effectiveness of dry ports. For example, Jeevan et al. (2018) analyzed the implementation of dry ports in Malaysia and

found that besides improving logistics efficiency, dry ports also contribute to the reduction of congestion and air pollution in major port areas. Environmental aspects are increasingly becoming a key focus in container yard site planning. Lam & Gu (2016) proposed a framework to evaluate the environmental impacts of container yard locations, including factors such as greenhouse gas emissions, noise pollution, and impacts on local ecosystems. They emphasized the importance of a holistic approach that con- siders not only operational efficiency but also long-term environmental sustainability.

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