30th

International Maritime Lecturers Association Conference

Split Croatia

www.imla30.org

International Maritime Lecturers Association

FACULTY OF MARITIME STUDIES

SYSTEM THINKING FOR CO_2 EMISSION OF CRUISE SHIPS IN EU

Selen Uygur[1,2*], Emre Duzenli[3], Gizem Kayisoglu[3], Pelin Bolat[4]

Abstract. The shipping sector contributes substantially to CO_2 emissions, with the cruise industry being a contributing factor. Although greenhouse gases including CO_2 emissions studies in the maritime sector are abundant, there is a compelling need to specifically focus on emissions generated by passenger ships visiting the EU. These vessels, with their high energy consumption and high port frequency in densely populated coastal zones, form a particular niche in the overall maritime emissions world. The aim of this study is to offer a system-wide perspective on the long-term effects of various policy interventions on CO_2 emissions from regularly visiting passenger ships calling at European ports. Systems thinking is a cognitive anchor that concentrates on comprehending entire systems and their interactions instead of just examining separate components in isolation. It is extremely useful when dealing with complex dynamic systems. The goal is to create a model that illustrates the system and the dynamics clearly and shows the necessity of understanding the dynamics to fully grasp the implications of CO_2 emissions from passenger ships berthed at EU ports. The study provides a conceptual dynamic model, illustrating complex causal interdependencies between variables across the different layers and how CO_2 emissions influence the system. It distinguishes between direct and induced effects, and potential policy interventions. Furthermore, causal loop diagrams (CLDs) provide action-oriented knowledge. The findings provide improved and disaggregated data on emission trends, which is key to focused policymaking and the development of tailor-made mitigation strategies. This report also complements the EU's Fit for 55 and FuelEU Maritime proposals in that it points out some regulatory loopholes and enforcement challenges applicable to passenger shipping. Moreover, it outlines the importance of integrative policy measures in realizing GHG reduction targets while giving valuable input to policymakers and industry stakeholders eager to be aligned with the European Green Deal ambitions.

Keywords: Maritime GHG Emissions; Passenger Ship; European Green Deal; System Thinking; System Dynamics; Causal Loop Diagram (CLD).

[1] Sakarya University of Applied Sciences, Sakarya, Türkiye

[2] Istanbul Technical University, Maritime Transportation Engineering Phd Program, İstanbul, Türkiye

[3] Istanbul Technical University, Department of Maritime Transportation Management Engineering, İstanbul, Türkiye

[4] Istanbul Technical University, Department of Basic Science, İstanbul, Türkiye

* **Corresponding author:** selenuygur@subu.edu.tr

https://doi.org/10.7225/imla30.41

1. INTRODUCTION

Estimates published by the IMO suggest that the maritime industry accounts for about 2.89 percent of all manmade greenhouse gas emissions globally. Should no action be taken, maritime sector emissions are expected to increase by 90-130 percent by 2050 against 2008 (IMO, 2020). Particularly with regard to cruise line operations, passenger vessels significantly add to marine sector emissions. Among all ship types, cruise ships emit the most carbon dioxide per vessel. Cruise ships' disproportionately negative environmental impact is shown by their higher carbon dioxide emissions per vessel than any other ship type. Because of their rather small overall capacity, cruise ships are less prone to emissions than other kinds of vessels (Dotto et al., 2023).

Growing passenger volumes and longer sailing distances translate into CO_2 emissions by cruise ships berthed in European Union ports as set to attain critical proportions in the near future. By virtue of their massive engine capacity, high energy consumption, and extended port stay, cruise ships emit high volumes of greenhouse gas (GHGs) per passenger. Of the fourth and fifth greenhouse gas reports released by the International Maritime Organisation (IMO, 2020), passenger ships contribute approximately 10% of the total emissions in the global shipping industry. The estimate represents the direct carbon dioxide emissions along with other greenhouse gases such as methane and nitrous oxide. The European Union (EU) is coming up with complete policy packages targeting the maritime transport industry to address environmental concerns as technological transformation occurs and emissions rise. Shipping, which operates within EU ports, has been included under the EU Emissions Trading System (EU ETS) and is subject to a carbon tax for emissions produced by large passenger ships, including cruise liners (European Commission, 2023). Alongside this legislation, measures like Fuel EU Maritime help enable the transition to cleaner fuels, shore electrification, and improved operational energy efficiency.

The European Maritime Safety Agency (EMSA) established the Monitoring, Reporting and Verification (MRV) system to facilitate overall monitoring of carbon emissions from vessels with more than 5,000 gross tons in Europe, thereby giving the shipping sector definitive and harmonized emission data. Large vessels calling at EU ports are required to report annual fuel consumption, CO_2 emissions, time of operation, and duration of port stays according to the MRV system. Cruise vessels fall under this category. The information enables analysis of maritime emissions in a variety of sectors and regions, enhancing the overall evaluation of the carbon footprint of the entire cruise ships. The most recent EMSA estimate for 2022 suggested that cruise ships visiting European ports emitted approximately 3 million tonnes of CO_2 (EMSA, 2023). This exceeds the entire yearly emissions of land transport for some of the smaller EU members, placing into perspective the extensive environmental impact of cruise tourism. Therefore, it is necessary to give incentive to reduce emissions for vessels visiting European ports and examine emission reduction scenarios from the standpoint of scientific methodology.

The current review points out a lack of modeling research that applies an integrated systems approach in assessing long-term behaviors, policy alternatives, and operational parameters of cruise transportation. Numerous strategies have been created over recent years, such as the implementation of alternative fuels, improvements in operations, and port electrification, aimed at mitigating the environmental impacts of cruise tourism. Significant environmental and social benefits have been shown from coastal energy use at ports (Rogosic et al., 2025). Without sacrificing passenger experience, alternative fuels including LNG can reduce CO_2 emissions up to 25%. More moderate changes are advised since policies like speed reduction and route optimization may lower emissions but negatively affect passenger satisfaction. On the other hand, the Carbon Intensity Indicator (CII) might not always provide fair results for cruise ships; hence, it is advisable to apply data-driven changes that remove temporal impacts (Braidotti et al., 2023). A sub-based study conducted in China shows that increased in-port activity during the epidemic reduced SOx emissions by as much as 59%; elements including speed and fleet management are therefore extremely important in environmental consequences (Chen et al., 2024). Concurrent with these results, a system dynamics model clarifies the effects of COVID-19 and economic situation on cruise port management, so helping decision-makers to develop sustainable policies (Alexopoulos, 2007).

Still, cruise ships have different running traits including higher energy consumption, passenger-driven service loads, and in-port dwell times. Using a System Dynamics approach, this paper investigates the main elements affecting CO_2 emissions from cruise ships visiting European ports so enabling the evaluation of long-term behavioral patterns in the framework of sectoral trends, policy interventions, and technological transformation scenarios. Jay W. Forrester developed the system dynamics methodology, a strong modeling method used to clarify, project, and improve the behavior of complex systems over time. Particularly those on industrial dynamics, urban dynamics, and environmental systems (world dynamics), Forrester's first models clearly showed how feedback loops, stock-flow relationships, and time lags in dynamic systems might generate unexpected results (Forrester, 1961; 1969; 1971). These approaches greatly helped to clarify both short-term and long-term behavioral patterns of systems, so increasing the visibility of the temporal results of policy interventions. Founded on basic variable structures including annual total cruise ship emissions, passenger capacities, average cruise optimizations, carbon footprint, and port emissions—the systems thinking model developed in this work is predicated on the model combines port emissions laws, emission control areas (ECA), and technological innovations for engines into policy tools. Inspired by several feedback loops through a systems thinking approach, the model aims to fully examine the variations in CO_2 emissions from the cruise fleet visiting European Ports, so providing decision-makers with the opportunity to evaluate strategic interventions likely to be long-term successful.

2. METHODOLOGY

By analysing interdependencies, feedback loops, delays and non-linear relationships between system components, systems thinking enables researchers to study complex socio-technical systems. Through this approach, not only the individual elements but also the dynamic interactions between these elements are assessed in a holistic manner. Thus, the behaviour of the system can be understood not only as the sum of existing structures, but also as a result of their interactions over time. Especially in areas such as policy making, environmental sustainability and technology management, systems thinking provides a powerful framework for gaining a deeper understanding of the causes of complex problems and developing effective intervention strategies (Sterman, 2000). Systems thinking makes it possible to trace cause-effect relationships over time in order to understand complex system behaviour and also emphasises that system structure is the main determinant of behaviour over time. According to Forrester, the structural characteristics of a system, information feedbacks and delays shape decision-making processes and therefore systems thinking provides an effective framework for analysis in areas such as policy development and strategic planning (Forrester, 1994).

According to Sweeney & Sterman (2000), the systems thinking approach should include the following features:

- Explain the emergence of dynamic interactions of system variables to understand the behaviour of the system.
- Should be able to show both positive and negative relationships of feedback mechanisms in the system.
- Should be able to provide an understanding of delays in the system.
- Students should be able to identify non-linear relationships and draw the boundaries of the mental model correctly.

Systems thinking is an approach that focuses on the whole while seeking solutions to problems. Figure 1 shows the four levels of systemic thinking.

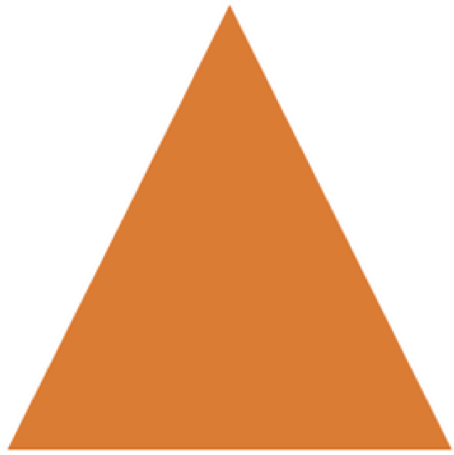

Figure 1. Four levels of System Thinking Model (Maani and Cavana, 2007).

Figure 1 uses an iceberg graphic to show the conceptual model including all four levels of systemic thinking. Being the main focus of daily life that requires immediate attention, events reflect only the surface layer of the system in this model and provide the main point of intervention. Apart from events, there exist systematic models explaining changing trends over time and the interactions among them. These models help one to understand the several interactions among the system. Basic mental models help people and companies to behave. These models capture people's values, beliefs, and assumptions, so clarifying the justification behind our responses to different situations (Maani and Cavana, 2007).

2.1. Casual-Loop Diagrams

Causal Loop Diagrams (CLDs) are one of the basic tools of systems thinking and are used to visualise feedback relationships between variables in complex systems. Jay W. Forrester, the founder of system dynamics, used these diagrams in the system models he developed at MIT in the 1950s and showed that CLDs play a fundamental role in modelling the rela-

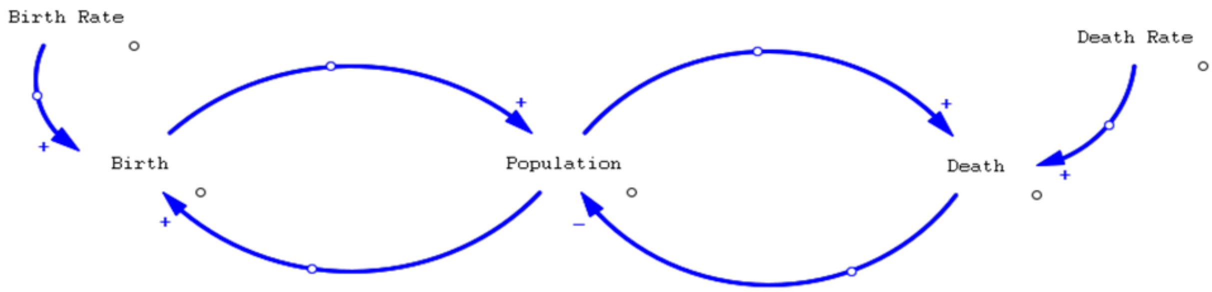

Figure 2. Population CLD

tionships between population, resource use and environmental factors, especially in studies such as World Dynamics and Urban Dynamics (Forrester, 1971). Forrester's approach demonstrated how CLDs can be used to explain the evolution of system behaviour over time. The cause and effect relationship between birth, death and population is visualised in Figure 2.

Figure 2 shows that a population increase results in higher birth rates, which subsequently increases birth rates, so producing a self-perpetuating cycle defining a reinforcing loop. Higher mortality rates brought on by population increase lead to population decline; this is a balanced loop. Reinforcing loops are positive feedback systems whereby an increase in one variable inside the system generates an increase in another variable, so amplifying the first variable and generating a self-perpetuating cycle of positive feedback. Such cycles can produce quick and perhaps explosive system behavior including boom, collapse, or growth (Meadow, 2008). Balancing loops are negative feedback systems whereby the increasing of one variable within the system activates another variable, so limiting the expansion of the first variable. These loops try to maintain system stability, so guiding it toward a goal or correcting deviations (Sterman, 2000).

Given these contributions, CLDs offer a crucial analytical framework for examining causal links in complex systems, forecasting system behavior, and formulating appropriate policy options. The illustration below depicts the correlation between Causal Loop Diagrams (CLDs), Forrester diagrams, and mathematical modeling techniques.

3. CRUISE VESSELS EMISSIONS SYSTEM THINKING APPROACH

Figure 3 shows that cruise vessels emissions reductions straties with system thingking approach. One of the primary factors affecting annual CO_2 emissions from cruise vessels is fuel consumption during voyages. An increase in voyage time often necessitates higher average vessel speed, which disproportionately elevates fuel usage and consequently CO_2 emissions.

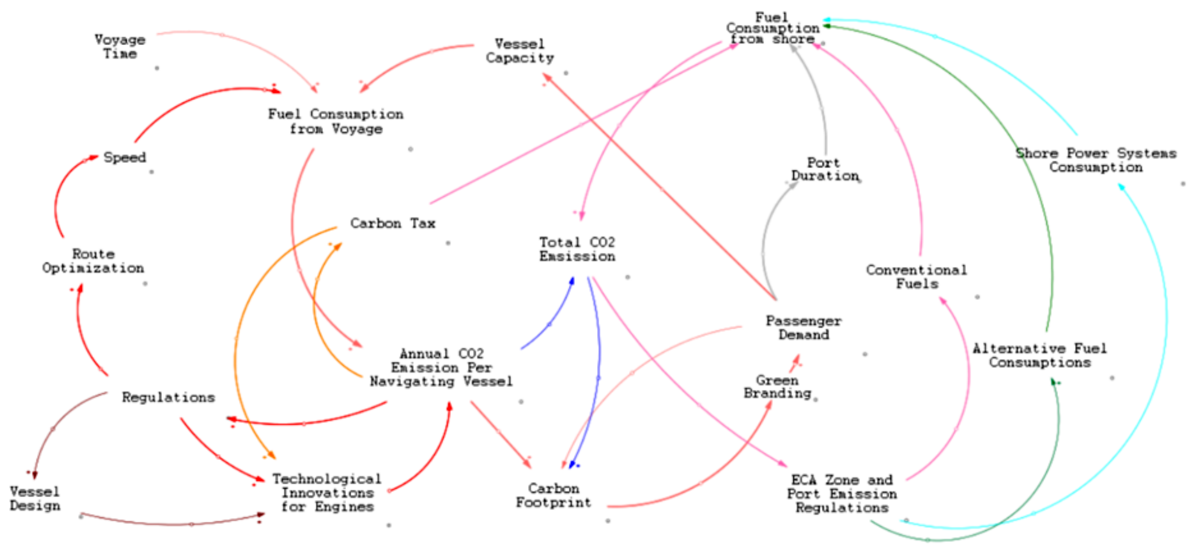

Figure 3. Cruise Vessels Emissions System Thinking Modeling

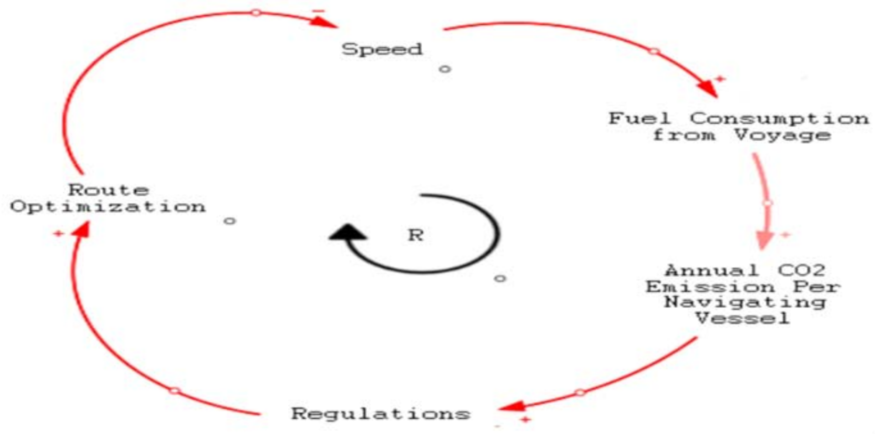

Figure 4. Emission Reduction Loop

This trend generates a reinforcing feedback loop with travel time, speed, fuel consumption, and emissions of pollutants. Conversely, technological innovations involving route optimization allow ships to be operated more economically at slower speeds, therefore reducing fuel consumption and associated emissions, fostering a further reinforcing cycle that includes a regulatory aspect. Environmental regulation encourages the application of energy-efficient ship design and technologies that render ships more efficient and reduce emissions. Economic mechanisms such as carbon taxes also assist in elevating these effects. More carbon pricing raises the costs of activities involving fossil fuel usage, thereby creating economic incentives for sustainable technology development. The interaction of financial sanctions and adherence to regulations form a feedback mechanism promoting the introduction of structural changes to limit emissions within the industry.

One of the principal determinants of total emissions is port stay duration. Increased port stays equate to increased consumption of energy resources for onboard hoteling operations, notably where ships do not partake in shore power options. Where the shoreside energy supply relies on conventional fuels, carbon dioxide emissions continue to accumulate during the ports-of-call duration. Higher passenger demand also results in port congestion, increasing port stays and forming a self-perpetuating cycle among demand, port stay, and emissions. Significant initial measures toward reduction of emissions by greater use of alternative fuels and shore power systems are emission control areas (ECAs) and port emission guidelines. Shore power offers the potential to eliminate shipboard engine operation at berthing, thereby reducing local CO_2 emissions and conventional fuel consumption.Likewise, expanded use of alternative fuels minimizes the consumption of fossil fuels. energy. Both developments represent balancing loops initiated and sustained through regulatory frameworks.

Figure 4 illustrates the loop for emission reduction strategies. The reinforcing causal loop shown in the model demonstrates the dynamic relationships among operational methods and regulation methods for emissions in shipping transport. Higher ship speed results in higher consumption of fuel on voyagers, thereby rising annual CO_2 emissions per ship on voyage. Tighter environmental policy is put in place in an effort to lower the environmental impact of shipping activities as a result of escalating emissions. The regulations above motivate ship operators to adopt route optimization methods, in an attempt to comply with emissions limits and concurrently save on fuel costs. Typically, route optimization leads to reduced average sailing speeds, which by themselves automatically translate to reduced fuel consumption and emissions. In this case, the system establishes a self-reinforcing loop in which regulatory demands and operational responses complement each other in facilitating the achievement of emissions reduction. This dynamic underscore the value of an aligned policy and operational approach in realizing the decarbonization goals of the shipping sector. The model focuses on the fact that complete transformation of navigational methods and policy implementation and technological advancement can lead to environmentally sustainable benefits.

Figure 5 is drawn to port emission reduction loop. The given causal loop diagram describes a balancing loop (B) that represents the interaction between the use of conventional fuel and port-based emissions regulation in maritime activities. With the increase in conventional fuel use, fuel use from shore also increases, resulting in high total CO_2 emissions. As a measure of the increasing emissions, there have been more stringent emission control area (ECA) reg-

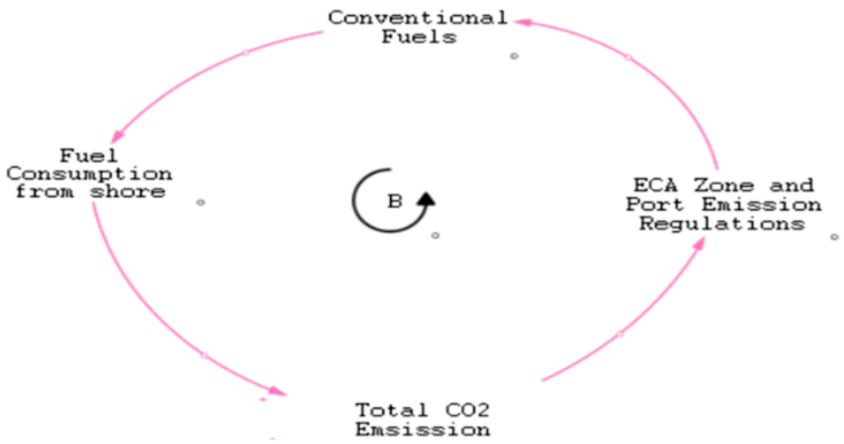

Figure 5. Port Emission Reduction Loop

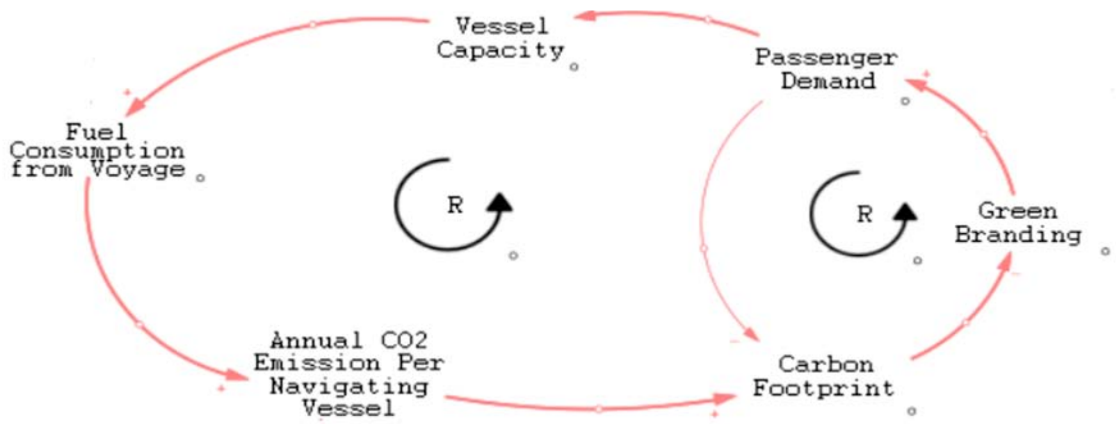

Figure 6. Carbon Footprint Loop

ulations and port emissions regulations designed to address this. Policy measures then lead to diminishing dependence on traditional fuels, hence leading to both onshore fuel decrease and overall CO_2 emissions reduction. This feedback loop serves as regulatory control, with the aim of stabilizing emissions by indirectly curbing traditional fuel consumption through policy.

Figure 6 presents the carbon footprint loop. The figure contains two reinforcing loops (R) that collectively explain the dynamic interactions among vessel operations, passenger demand, and environmental performance of the cruise shipping industry. An increase in vessel capacity in the first loop results in increased fuel consumption along voyages, which, in turn, raises the annual CO_2 emissions per navigating vessel and adds to the sector's carbon footprint.

In the second reinforcing loop, the growing significance of carbon footprint makes companies invest in green branding initiatives with the aim of enhancing their environmental reputation. This evolution in green branding creates a greater demand by travellers, which in turn requires vessel capacity to be expanded. These reinforcing processes are a typical example of how market-driven environment-focused approaches can at the same time generate opportunities and challenges in managing emissions and addressing growing demand in the cruise sector.

Figure 7 is depicted to integrated port decarbonation loop. The causal loop diagram extended combines several balancing feedback structures (B) that reflect the intricate dynamics among passenger demand, port operations, fuel types, and emission reduction actions in maritime transport. Rising passenger demand lengthens port duration, thereby increasing fuel usage from shore-based activities. Higher shore-based fuel consumption is part of the total CO_2 emissions that will initiate regulatory action in the form of ECA zones and port emission standards to curtail conventional fuel consumption. The illustration also features the installation of shore power systems and alternative fuel use as further mitigation strategies. Since shore power systems and alternative fuels are utilized, the demand for conventional fuels is reduced, also lowering emissions.

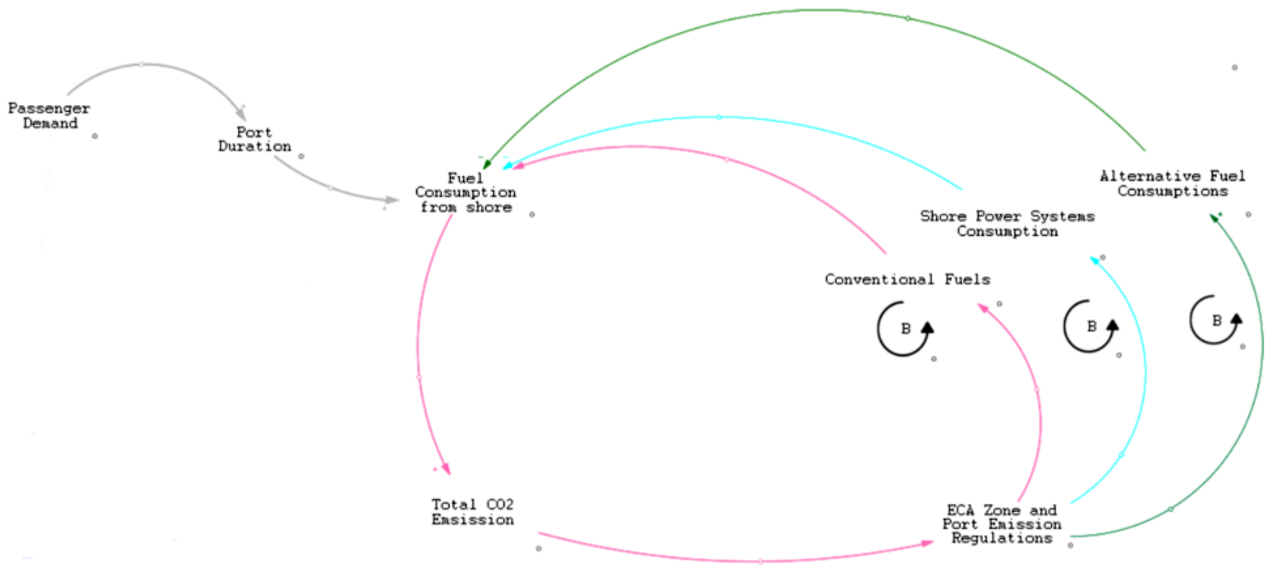

Figure 7. Integrated Port Decarbonization Loop

The balancing loops stress the necessity of coordinated technological and regulatory measures in bringing about sustainable port operation and lowering maritime emissions amidst increasing pressures of passengers' demand.

4. DISCUSSION

The causal loop diagram in this research illustrates the intricate interdependencies that influence carbon dioxide (CO_2) emissions from cruise ship operations in European ports. Intervention opportunities are offered by enhanced navigation, but several dimensions of operation such as route optimization, ship speed, and trip duration create self-reinforcing feedback loops with a great influence on yearly emissions. Since there is no shore power facility, shore-based dynamics—e.g., longer port stays—intensify emissions (Mocerino and Quaranta, 2022). The lockdown phase of the COVID-19 pandemic demonstrated that operational stoppages can drastically cut port emissions. Technological innovation, particularly by harnessing hybrid systems and alternative fuels such as LNG (Kizielewicz, 2021), is central to emission-mitigation planning. Regulatory mechanisms like EEDI and SEEMP, as well as the financial tools like carbon taxes and port emission rules, which nudge operators towards cleaner technologies and operations to continue pursuing decarbonization targets, help drive these developments.

Some of the important variables in the system dynamics model developed for this research interact directly with regulatory systems and hence with technical and operational pathways to decarbonization. ECA Zone and Port Emission Regulations are the primary policy levers that affect fuel selection and the utilization of shore power. Tighter Emission Control Areas (ECAs) compel operators to cut sulfur content and particulate emissions, thereby encouraging the adoption of alternative fuels such as biofuels, liquefied natural gas (LNG), and onshore generation of power onboard. This regulatory development is in line with developments in engine technology, whereby compliance demands facilitate the adoption of advanced propulsion systems and emissions control technologies. Furthermore included into the system are design and operational efficiency requirements included into worldwide regulatory systems including the Energy Efficiency Design Index (EEDI) and the Ship Energy Efficiency Management Plan (SEEMP). Legislation directly affects the model variables, technical and operational efficiency stocks. New vessels have to follow EEDI criteria, which calls for improved ship design and hence changes the fleet's average fuel consumption over time. Parallel to this, SEEMP addresses recurring changes in operations impacting voyage optimization, speed reduction plans, fuel consumption-impacting maintenance work, and consequently CO_2 emissions.

The integration of these components in the architecture reveals a multi-faceted yet consistent policy context in which technical efficiency standards (i.e., EEDI and SEEMP), fiscal measures (i.e., carbon taxation), and emissions regulation at the port level complement each other. Altering operational practices, investment strategies, and technological directions within the cruise shipping sector, this joint strategy highlights that well-crafted regulatory frameworks not only facilitate technological advancements but also contribute to making methodical decarbonizing trajectories. Passengers' response to green performance on the demand side generally offsets agent. As overall emissions increase, the carbon footprint of each vessel grows, thus compromising green branding and ultimately lowering passenger demand. In line with behavioral data showing green consumers are always more demanding pressures on the travel and transportation industries, the feedback form above naturally reflects an inherent growth limit. Port emission rules and Emission Control Areas (ECAs) help to augment the creation of feedback systems tracking the use of alternative fuels and shore power. Such legislations limit the use of traditional fuels externally and mandate compliance with inbuilt enforcement mechanisms. Their incorporation in the Comprehensive Low-Emission Development (CLD) indicates the comprehensive nature of marine policy, whereby operational adjustments, technological advancement, and policy frameworks must converge in consensus.

5. CONCLUSION

In the present research, an improved causal loop diagram (CLD) was developed for examining the dynamic relationships influencing CO_2 emissions from cruise ships, for instance, in European port activities. The model integrated operational, technological, regulatory, and behavioral variables in an attempt to provide a comprehensive explanation of the emission trajectories and the intervention points.

The study established that emissions from cruise ships are not the result of independent determinants; rather, they arise through a combination of self-reinforcing and balancing feedback loops. Specifically, factors pertaining to a voyage like routing optimization, speed, and fuel consumption are included in the self-sustaining patterns of emissions. On the contrary, regulatory policies, such as carbon pricing, port standards and Emission Control Areas (ECAs), put in place compensatory measures which discourage fossil fuel consumption while promoting cleaner substitutes, such as shore power and alternative fuels. The model also pays strong attention to demand-side behavior. The awareness among travelers of the environmental consequences, as reflected in green branding efforts and familiarity with carbon footprints, can impact demand and act as a counterweight to unsustainable trends in growth. At the same time, the status of technological development and the readiness of port infrastructure, in particular its potential for shore power, significantly influences the shape of the long-term emissions profile in the sector.

In general, carbon-footprint minimization for cruise shipping in port stops has to be a holistic endeavor. Emissions reduction efforts should transcend individual technical solutions and address the entire complex feedback mechanism. Policymakers, port authorities, and industry stakeholders need to collaborate to formulate measures that not only reduce direct emissions but also change the fundamental drivers for the emissions. Follow-on research may expand the model to incorporate economic performance measures or social acceptance metrics, thereby rendering it even more relevant to policy and actual practice.

Acknowledgements: This study is partially supported by Istanbul Technical University Scientific Research Projects - Project ID: FHD-2025-47272.

Conflict of interest: The authors declares that there is no conflict of interest.

REFERENCES

Alexopoulos, A. B., 2007. Introducing system dynamics modelling into the passenger and cruise markets focusing on the marine manpower. International Journal of Applied Systemic Studies, 1(4), 436-449. Available at: https://doi.org/10.1504/IJASS.2007.019305

Braidotti, L., Bertagna, S., Rappoccio, R., Utzeri, S., Bucci, V., & Marinò, A., 2023. On the inconsistency and revision of Carbon Intensity Indicator for cruise ships. Transportation Research Part D: Transport and Environment, 118, 103662. Available at: https://doi.org/10.1016/j.trd.2023.103662

Chen, Q., Lau, Y. Y., Kanrak, M., Sun, X., Zhang, P., & Tang, Y. M., 2024. Using a bottom-up method to assess cruise ship activity impacts on emissions during 2019–2020 in China. Heliyon, 10(5). Available at: https://doi.org/10.1016/j.heliyon.2024.e27101

Dotto, A., Satta, F. & Campora, U., 2023. Energy, environmental and economic investigations of cruise ships powered by alternative fuels. Energy Conversion and Management, 285, 117011. Available at: https://doi.org/10.1016/j.enconman.2023.117011

EMSA, 2023. Thetis-MRV Public Emissions Report 2022. European Maritime Safety Agency. Available at: https://mrv.emsa.europa.eu, accessed on: [10.05.2025].

European Commission, 2023. EU Emissions Trading System (EU ETS). Available at: https://climate.ec.europa.eu/eu-action/eu-emissions-trading-system-eu-ets_en, accessed on: [14.06.2025].

Forrester, J.W., 1961. Industrial Dynamics, 1st Edition, Cambridge, MA: MIT Press.

Forrester, J.W., 1969. Urban Dynamics, 1st Edition, Cambridge, MA: MIT Press.

Forrester, J.W., 1971. World Dynamics, 1st Edition, Cambridge, MA: Wright-Allen Press.

International Maritime Organization (IMO), 2020. Fourth IMO GHG Study 2020. Available at: https://www.imo.org/en/OurWork/Environment/Pages/Fourth-IMO-Greenhouse-Gas-Study-2020.aspx, accessed on: [14.06.2025].

Kizielewicz, J., 2021. Eco-trends in energy solutions on cruise ships. Energies, 14(13), 3746. Available at: https://doi.org/10.3390/en14133746

Maani, K, and Cavana, R., 2007. Systems Thinking and Modelling – Managing Change and Complexity, 2nd edition, Pearson Education, Prentice Hall

Mocerino, L., & Quaranta, F., 2022. How emissions from cruise ships in the port of Naples changed in the COVID-19 lock down period. Proceedings of the Institution of Mechanical Engineers, Part M: Journal of Engineering for the Maritime Environment, 236(1), 125-130. Available at: https://doi.org/10.1177/14750902211028421

Rogosic, M., Stanivuk, T. and Lucaci, D., 2025. A study on the application of shore-side power as a method to reduce the emissions of greenhouse gases by cruise ships. Journal of marine science and engineering, 13(3), p.453. Available at: https://doi.org/10.3390/jmse13030453

Sweeney, L. B., & Sterman, J. D., 2000. Bathtub dynamics: initial results of a systems thinking inventory. System Dynamics Review: The Journal of the System Dynamics Society, 16(4), 249-286. Available at: https://doi.org/10.1002/sdr.198