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LIVING LABS IN SHIPPING: ADVANCING THE UN SUSTAINABLE DEVELOPMENT GOALS

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ABSTRACT:

This study investigates the role of Living Labs (LLs) in creating innovative solutions for sustainable shipping, explores stakeholder involvement, issues addressed, methodologies employed, and the alignment with UN Sustainable Development Goals (SDGs).

Design/Methodology/Approach: *This study utilizes a qualitative approach to examine various typologies of living labs in the shipping sector. A literature search in April 2025 identified 56 documents from the SCOPUS database, with nine selected for in-depth analysis. Additional information was gathered from professional literature and industry sources, resulting in eight indicative living labs. The study aims to tabulate these cases and discuss the involved stakeholders, specific issues addressed, and the Sustainable Development Goals (SDGs) they support.*

Findings: *LLs are emerging as co-creation methods for innovative solutions in the shipping industry, primarily in the Global North. These LLs, mostly established after 2018, focus on digitalization, supply chain optimization, energy efficiency, decarbonization, and waste management. Key stakeholders align with the Triple Helix model (government, industry, academia), with a potential benefit from incorporating civil society (Quadruple Helix). The LLs contribute to multiple SDGs, notably SDG 9 (Industry, Innovation, and Infrastructure) and SDG 17 (Partnerships for the Goals).*

Research Implications/Limitations: *A gap exists in the literature regarding the actual impact assessment of shipping LLs. The study is limited by its desk research approach, relying solely on literature. Future research should incorporate in-depth case studies with interviews for a more realistic understanding.*

Practical Implications/Limitations: *The UN SDGs can serve as a framework for evaluating shipping innovations across environmental, social, and economic dimensions. Efficient LL processes, once validated, can be embraced by the shipping industry, contributing to its sustainability.*

Originality: *The study provides insights into the emerging role of LLs in the shipping industry and their alignment with the UN SDGs, offering a foundation for future research and practical implementation in pursuit of a more sustainable maritime sector.*

KEY-WORDS: Innovation in Shipping, Living Laboratories, Shipping Decarbonisation, Shipping Digitalization, UN SDGs.

1. INTRODUCTION

Shipping provides substantial benefits to society by facilitating widespread freight transportation that is not only cost-effective but also energy-efficient. It accounts for the transport of more than 80% of global goods by volume (UNCTAD, 2024). Shipping effectively connects producers and consumers in a globalized world, facilitating trade at relatively low costs. It is especially significant for countries in the Global South, which have pressing needs for food and resources. Consequently, shipping plays a crucial role in advancing several Sustainable Development Goals (SDGs) (UN, 2017; IMO, n.d.), particularly the most critical ones for human welfare, such as SDG 1 – No Poverty and SDG 2 – Zero Hunger (Figure 1).

Figure 1. The 17 Sustainable Development Goals of the United Nations

The marine industry is anticipated to face numerous challenges, including evolving regulations, climate change, energy shortages, and rapid technological advancements (Zaman et al., 2017). Fuelled by advancements in sensor technology, IT, automation, and robotics, technological development is evident across all marine sectors. To effectively adapt to forthcoming regulations and market pressures, the industry must maintain its rapid pace of development over the next decade.

One of the most pressing global environmental challenges of today, with potentially harmful impacts on the economy, social welfare, and the environment, is climate change. Today's shipping is almost entirely dependent on fossil fuels, and therefore, it is associated with externalities such as greenhouse gas emissions and air and marine pollution. The sector is estimated to contribute to approximately 2.5% of total global greenhouse gas emissions, compared to 16% from road transport (Jaramillo et al., 2022). Since 2011, the International Maritime Organization (IMO) has adopted measures to improve the energy efficiency of ships, such as the Energy Efficiency Design Index (EEDI) and the Ship Energy Efficiency Management Plan (SEEMP). In accordance with the Paris Agreement, the IMO launched its 2023 revised strategy with the strategic goal of achieving net-zero emissions from shipping by 2050. To reach this ambitious target, alternative fuels like biofuels, hydrogen, ammonia, and methanol must increase their market share from 0% in 2023 to 80% by 2050 (IMO, 2023). This necessitates a radical transformation of the energy landscape in shipping within the next 25 years. The timeline is further compressed by the fact that a ship built today has an operational lifespan of around 20 years, meaning that current fuel choices will significantly impact future performance, adding another layer of complexity to the issue.

The necessary transformations should prioritize not only technological innovation but also stakeholder involvement. This ensures that changes are

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relevant and responsive to real-world problems and that envisioned solutions are seamlessly created, vetted, and implemented by the shipping industry. The International Maritime Organization's (IMO) success in shipping exemplifies the effective implementation of stakeholder engagement. While the IMO serves as a global forum where member states make final formal decisions, the lengthy and meticulous process of drafting regulatory instruments is guided and shaped by the participation of numerous shipping sector stakeholders, including non-governmental and intergovernmental organizations (Tan, 2005).

An emerging methodology for effective citizen and stakeholder participation in the co-creation of innovation is the concept of the living labs (LLs). According to Hossain et al. (2019), a living lab is a physical or virtual space to solve societal challenges, especially in urban areas, by bringing together various stakeholders for collaboration and collective ideation. For Mastelic (2019), "a living lab is an innovation intermediary, which orchestrates an ecosystem of actors in a specific region. Its goal is to co-design products and services in an iterative way with key stakeholders in public-private people partnerships and in a real-life setting. One of the outcomes of this co-design process is the co-creation of social value (benefit). To achieve its objectives, the living lab mobilizes existing innovation tools and methods or develops new ones". Finally, according to ENoLL (European Network of Living Labs), living labs are open innovation ecosystems in real-life environments using iterative feedback processes throughout a lifecycle approach of innovation to create sustainable impact (ENoLL, n.d). The LLs are experimentation environments that foster co-creation and open innovation among the main actors of the Quadruple Helix Model, namely citizens, government, industry, and academia (ENoLL, n.d). Living labs, therefore, are inspired by traditional scientific laboratories, serving as environments for experimentation and innovation. However, unlike the controlled and artificial settings of the traditional labs, LLs operate in real-world contexts. The human element is a critical component of their processes, encompassing both the participants (which are stakeholders or end users) and the overseeing organization. Furthermore, LLs are more than mere spaces for discussion, education, or awareness raising, such as workshops or focus groups. Their primary goal is to iteratively develop innovative solutions to real-world problems.

In this landscape, it is also important to recognize that regulations or innovative solutions intended to solve one problem can sometimes worsen another. An example is the introduction of hydrogen as a maritime fuel, which, despite its zero operational GHG emissions, relates to substantial upstream emissions from its production, transportation, and storage. Moreover, unresolved safety concerns and the significantly higher costs compared to traditional fuels pose further challenges (Kostidi et al., 2025). Consequently, any effort to address a specific problem should account for its related environmental, economic, and social impacts (Kotrikla, 2017) to promote balanced and sustainable progress. A comprehensive framework that could guide, shape, and evaluate shipping innovations is their alignment with the UN's 17 Sustainable Development Goals (UN, 2017), which strive to eliminate poverty, ensure prosperity, and safeguard the planet by 2030.

In this framework, the aim of the study is to investigate the role of living labs in the creation of innovative solutions for sustainable shipping. The stakeholders involved, the specific issues addressed, the methodologies employed, and the results achieved are searched with reference to specific cases. Finally, the connection between the living labs' work in the realm of shipping and the UN's sustainable development goals is explored.

The reminder of this paper is structured in the following way: At first the methodology is described. Then, eight cases of living labs in the shipping realm are presented. Next, based on the cases presented and the scientific literature reviewed, discussion is made on the characteristics, main actors and stakeholders, scale and complexity, and evaluation of the LLs in shipping, and their alignment with the UN SDGs. Finally, the conclusions of the paper are presented.

2. METHODS

This study uses a qualitative approach to investigate different typologies of living labs in the realm of shipping. At first, the scientific literature was searched in April 2025. SCOPUS database was searched (article title, abstract, and keywords) using the terms ("Living Lab*" OR LLs) AND (port OR shipping OR maritime). The search identified 56 documents. After reviewing the abstracts, 9 of them were chosen for further analysis, while the

remaining documents were excluded because they were either irrelevant to the study's focus or provided only brief references to the topic.

This information was completed by searching the internet for data from the professional literature including documents from governmental, intergovernmental and non-governmental organizations, the shipping industry and the press.

Specific cases of living labs in shipping were retrieved. The cases that included information in most of the following fields were considered for further analysis: Segment of the shipping industry and subject area, stakeholders/participants, approximate date of launching, facilitating organization, and geographical area. These selection criteria resulted in an indicative but not exhaustive collection of eight LLs in shipping. The next step was to tabulate the information on the LL cases in shipping and discuss the stakeholders involved, the specific issues addressed, and the SDGs served by the LLs. A diagrammatic flow of the main steps of the methodology is presented in Figure 2.

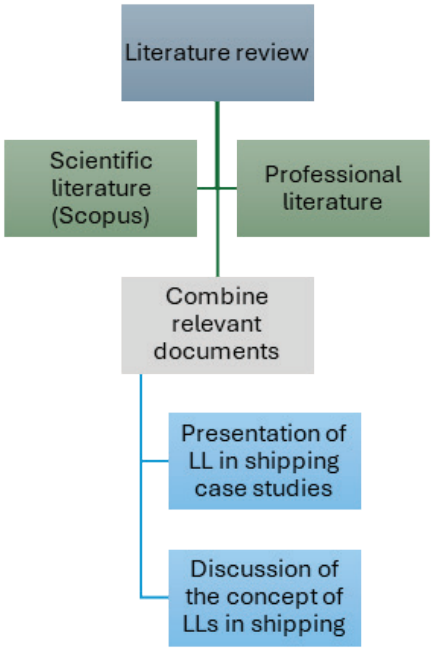

Figure 2. Diagram of the methodology of the study

3. RESULTS AND DISCUSSION

3.1. Cases of LLs in Shipping

Information on living labs in the shipping industry is presented below, based on publicly accessible data in the following areas: Shipping Segment, Subject Area, Stakeholders/Participants, Date of Commencing the Activities, Organization, and Geographical Area. The LL are presented in chronological order of their launching date.

Living Lab Maritime - LABSKAUS

Living Lab Maritime – LABSKAUS was facilitated by Carl von Ossietzky University of Oldenburg in Northwestern Germany, and it appeared in the literature in 2014 (Bolles and Hanh, 2014). The idea is that the development of safety-critical systems such as highly automated and autonomous vessels brings the need to establish a test environment (or 'testbed') close to the real world (in addition to simulative test environments) to support in situ their development, testing, demonstration, validation and certification process. Consequently, the Living Lab Maritime – LABSKAUS is basically a highly sophisticated testbed that provides services such as a reference waterway, a research boat, sensor infrastructure to correlate with the environment, a mobile bridge system, and a Vessel Traffic Services (VTS) System. This complex system supports the solution of technical problems but does not have educational features and is aligned mainly with SDG 9, which has the core aim to foster innovation, and SDG 8, which focuses on decent work and economic growth (Figure 1, Table 1).

MPA Singapore LL

The LL, run by the Marine Port Authorities of Singapore, was launched around 2018 and aims to provide a real operating environment and maritime data for the testing and validation of new solutions/technologies in the port of Singapore, one of the world's busiest hub port and waterways (MPA of Singapore, n.d.). MPA Living Lab aims to bring together the process owners, technology providers, and/or researchers to co-innovate, test-bed new systems, and bring technological and engineering solutions closer to market. It has spaces for the housing of maritime data hubs, remote pilotage, and next generation vessel traffic management experimentation. Physical testbeds at sea, such as designated anchorages, facilitate the trials of marine drones, autonomous vessels, and wireless communication technologies in the port environment. In addition, it includes the co-location of maritime companies, such as Wartsila's Global Acceleration Centre, in the same vicinity. The

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MPA Singapore LL focuses overall on data analytics and intelligent systems, autonomous systems and robotics, smart and innovative infrastructure, and safety and security, directly serving SDG 9, which has the core aim to foster innovation, and indirectly SDG 8, which focuses on decent work and economic growth. In addition, MPA LL experiments on environmental protection, thus supporting SDG 7 on affordable and clean energy, SDG 12 on responsible consumption and production, SDG 13 on climate action, and SDG 14 on protecting life below water. Finally, the co-location of maritime companies in the same vicinity enhances SDG 17 by fostering cooperation.

5G-LOGINNOV Projects' LL

In the framework of the 5G-LOGINNOV Project, part of the European Commission's 5G-Public Private Partnership, three LLs were implemented in Athens (port of Piraeus), Greece, Hamburg, Germany, and Luka Koper, Slovenia (5G-LOGINNOV, 2020; Catana et al., 2023; Kountche et al., 2023). The aims of the partnership (SDG 17) that will be implemented and tested in real operating conditions in the three living lab environments are to minimize the environmental impact of ports (SDGs 7, 13 and 14), to reduce congestion around the port area and disturbance to the cities (SDG 3, SDG 11), to represent a pillar of economic development and business innovation for the region (SDGs 8) and to facilitate the integration of the autonomous truck platoons of the future (SDG 9). The tools, innovative concepts, applications, and devices implemented include the Internet of Things (IoT), data analytics, next-generation traffic management, Cooperative, Connected, and Automated Mobility (CCAM), and the EU 5G logistics corridor.

The Living Lab of the Port of Valencia

The LL of the port of Valencia was announced in 2021 with the objective of improving the logistics sector and promoting new technologies and business opportunities in its immediate environment while improving the sustainability and quality of Valencia and the Valencian Community (Valencia Port, 2021). The LL platform facilitates the exchange of information in real time between port authorities, terminals, tugboats, pilots, and moorers so that all the information associated with the operation is available to all interested parties, enabling better planning, coordination, and decision-making. Valencia Port LL is a space to promote sustainability and decarbonization projects (SDG 13) such as renewable energies, efficient management of energy networks (SDG 7) or circular economy (SDG 12); new business opportunities in the logistics chain (SDG 8); the digitization of port processes (SDG 9); and integration with the immediate surroundings, both the city of Valencia and the Valencian Community (SDG 11). Participants in the LL are local authorities, representatives of the port logistics cluster, and start-ups fostering cooperation to achieve the goals (SDG 17).

The Pier Living Lab

The PIER (Port Innovation, Engagement, & Research) is an LL launched by the Halifax Port Authority in Canada in 2021 (PIER, n.d.) PIER LL engages tech companies, local and global supply chain partners, researchers, SMEs, and startups to solve problems and explore new technologies in a live environment (SDG 17). It focuses on three key areas: supply chain and logistics, supporting an interconnected Port City, and maritime policy development with sustainability as a core function and outcome in each. The vision is a future port with lower emissions. Through workforce development initiatives, a capable, diverse, engaged workforce, including racialized groups, is built. The PIER LL is a tool to advance UN SDG 4 (Quality Education), SDG 7 (Affordable and Clean Energy), SDG 8 (Decent Work), SDG 9 (Innovation), SDG 10 (Reduced Inequalities) SDG 11 (Sustainable Cities), SDG 12 (Responsible Consumption and Production), SDG 13 (Climate Action), SDG 14 (Life Below Water) and SDG 10 (Reduced Inequalities).

Techlog's Project Living Labs

Under EU's TECHLOG project that aims to offer technological and educational tools through which international trade, logistics, and transport students or professionals can simulate real-life operations, two permanent cross-border living labs were established, the Western (Cagliari, Italy, and Sfax, Tunisia) and Eastern (Beirut, Lebanon, and Alexandria, Egypt) in 2022 (TECHLOG, 2022), all of them transfer technologies for logistics innovation in Mediterranean area (SDG 10). These cross-border open labs were created to facilitate technology transfer between research centers specializing in driving simulators and transport communities, thus supporting SDG 9 and SDG 17. The project pursued

a dual objective: Firstly, to craft inventive training protocols for practitioners (SDG 4), accompanied by proposals for related public policies (SDG 16), and secondly, to offer recommendations for optimizing business processes (SDG 8). The emphasis was on fine-tuning and optimizing Virtual Reality (VR) and Augmented Reality (AR), utilizing the synergy of Artificial Intelligence AI and the Internet of Things (IoT) to seamlessly integrate them for specific tasks and varying levels of control. The living labs played a crucial role in the development and testing of new training protocols (TECHLOG, 2023).

Newlab-Michigan Central

The Port of Monroe is Michigan's (USA) only port on Lake Erie and serves as the gateway to the State of Michigan's far-reaching multimodal transportation network. Located on the deep-draft frontage of the River Raisin, with direct rail access and immediate proximity to major freeways, the Port of Monroe represents the closest convergence of major freight assets anywhere in the region. In 2023, the Port of Monroe was announced as the first partner in the Newlab-Michigan Central testing network, a portfolio of multimodal pilot sites in Southeast Michigan that will serve as platforms to enable rapid testing of new technologies in real-world conditions (Port of Monroe, n.d.). As the on-the-ground project facilitator, Newlab is assembling a network of organizations and startups to drive the recently launched Multimodal Logistics Challenge, an initiative designed to accelerate cross-sector collaboration (SDG 17) around low-carbon (SDG 7 and SDG 13) and multimodal logistics (SDG 8, SDG 9, and SDG 11).

FOREMAST LLs

Under the FOREMAST project, funded by Horizon Europe, three LLs were realized in 2024 to support solutions for European coastal and inland or congested urban regions, implementing vessel prototypes and a Digital twin platform (FOREMAST, 2025). The LL of Ghent develops and tests a sustainable vessel solution in the Ghent region to shift the transport of goods from roads to water, contributing to a greener urban distribution. The LL of Caen develops and tests a new innovative catamaran vessel design and prototype tailored for urban goods transport. Finally, the LL in Galati, Romania, demonstrates replicability and develops an optimized vessel concept addressing the specific inland and Black Sea coastal navigation areas located in South-Eastern Romania. The LLs contribute to SDG 7, SDG 13, and SDG 11 by shifting the traffic to a more energy-efficient mode (shipping compared to road transport) whereas at the same time, promote health and well-being by reducing road congestion and air pollution (SDG 3) and foster innovation (SDG 9) through partnerships (SDG 17).

3.2. Discussion of the Living Lab Concept in Shipping

Table 1: Living Labs for the co-creation of innovation in shipping (list in chronological order of announcement)

Name	Shipping Segment	Subject	Stakeholders/ Participants	Activity since (approx.)	Organized/ facilitated/ led by	Area/City/ Country	UN SDGs
Living Lab Maritime - LABSKAUS	Canals and harbors	Navigation safety	n.a.*	2014	Carl von Ossietzky University of Oldenburg	Oldenburg, Northwestern Germany	8, 9
MPA Living Lab	Ports	Smart, intelligent, and autonomous systems (marine drones, autonomous vessels, and wireless communication technologies)	Industry partners (process owners and technology providers), researchers, and local universities	2018	MPA Singapore	Singapore	7, 8, 9, 12, 13, 14, 17
5G-LOGINNOV Projects' LL	Ports, freights, and the logistic supply chain	Environmental impact minimisation supported by tools such as IoT, data analytics, next generation traffic management, Cooperative, Connected, and Automated Mobility (CCAM), and the EU 5G logistics corridor	ICT manufacturers, telecommunications operators, service providers, SMEs, and Research Institutions	2020	5G-LOGINNOV project	Piraeus, Greece Hamburg, Germany Koper, Slovenia	3, 7, 8, 9, 11, 13, 14, 17

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Name	Shipping Segment	Subject	Stakeholders/ Participants	Activity since (approx.)	Organized/ facilitated/ led by	Area/City/ Country	UN SDGs
Valencia port LL	Ports and Logistics	Digital transformation, sustainability, climate adaptation	Local authorities, representatives of the port logistics cluster, and start-ups	2021	Port of Valencia	Valencia, Spain	7, 8, 9, 11, 12, 13, 17
The Pier Living Lab	Ports, shipping, land	Maritime transportation and logistics, ports, policies	Tech companies, local and global supply chain partners, researchers, SMEs, and startups	2021	Halifax Port Authority	Halifax, Canada	4, 7, 8, 9, 10 11, 12, 13, 14, 17
Techlog's Living Labs	Logistics	Advanced technologies like Artificial Intelligence (AI), Virtual Reality (VR), and Augmented Reality (AR).	Maritime and transport companies and institutions, chambers of commerce, port authorities, terminal operators, training agents, universities	2022	University of Cagliari and Arab Academy for Science, Technology and Maritime Transport	Western LL (Cagliari, Italy, and Sfax, Tunisia) Eastern LL (Beirut, Lebanon, and Alexandria, Egypt)	4, 8, 9, 10, 16, 17
Newlab-Michigan Central	Logistics, Inland ports	Acceleration of cross-sector collaboration around low-carbon, multimodal logistics	A network of organizations and startups	2023	Michigan Central	Port of Monroe, Lake Erie, Michigan, USA	7, 8, 9, 11, 13, 17
FOREMAST LLs	Inland/ Coastal/ Urban	Integrating practical advancements in vessel automation alongside innovative green propulsion and ship design.	-	2024	-	Ghent, Belgium Caen, France Galati, Romania	3, 7, 9, 11, 13, 17

*Nonavailable

3.2.1. Characteristics:

The living labs listed in Table 1 suggest they are currently emerging intervention methods for co-creating innovative solutions to real-world problems, primarily in the Global North. As Table 1 shows, the oldest shipping-related LL began in 2014, with the remaining seven initiatives starting after 2018. Geographically, most shipping LLs are in Europe (Belgium, France, Germany, Greece, Italy, Romania, Slovenia, and Spain), with others in Africa (Egypt and Tunisia), America (USA and Canada), and Asia (Singapore and Lebanon). This European concentration may be due to EU initiatives promoting citizen and stakeholder participation in policy, research, and innovation, including funding programs like HORIZON (EC, n.d.).

3.2.2. Main actors:

Based on the shipping LL examples discussed (Table 1) and the scientific literature, the main actors involved appear to align in most of the cases with the Triple Helix model of innovation, encompassing representatives from government, industry, and academia (Ranga and Etzkowitz, 2015). This reflects the real-world problems that these LLs aim to address, primarily digitalization, vessel automation, supply chain optimization, energy efficiency and decarbonization, waste management, and the circular economy. The drivers behind selecting these specific problems are complex (Rodrigue, 2010), but key factors include regulations at the national, regional (EU), and international (IMO) levels, as well as the need to enhance the operations and competitiveness of shipping and ports within the dynamic global environment. Consequently, shipping LLs focus on inventing innovative solutions and systems led by academia and industry, tested within ports and shipping companies, and supervised by policymakers for regulatory compliance. More specifically, the roles of the different actors within the Triple Helix model in the shipping arena (maritime shipping and ports) are (Rodrigue, 2010; Šekularac-Ivošević and Milošević, 2019; Polydoropoulou et al., 2025):

- **Port authorities:** Port authorities are key actors. Beyond managing daily operations and setting strategic goals, they provide a unique real-world environment for experimentation – a fundamental requirement for LLs. Their involvement ensures solutions are not only innovative but also practical, feasible, and seamlessly integrated into existing port workflows.

- **Shipping companies:** Their experience in managing cargo, ships, and the logistics chain, combined with their understanding of port operations, makes them invaluable for optimizing real-world operational and technological aspects. Specifically, they contribute to improvements in cargo handling, reduced waiting and hoteling times, optimized ship speed and weather routing, and the testing of new fuels and technologies aimed at decarbonization and digital solutions.

- **Technology providers:** These actors develop digital solutions (including IoT and automation tools) and low-carbon energy solutions. Their key role is to collaborate closely with port authorities and shipping companies, adapting these solutions to meet the specific challenges and needs within the shipping industry.

- **Policy makers and government representatives:** Policymakers and government representatives can improve regulations by gathering input from the shipping industry on compliance challenges. They play a critical role by providing policy goals and economic support to the LL, and their involvement is essential for aligning the LL's innovations with relevant regulations.

- **Researchers and academia members:** Researchers and academia members offer essential knowledge, innovative solutions, and data analysis expertise. They actively seek opportunities to pilot their ideas in real-world settings to test their effectiveness and identify areas for improvement. Additionally, they can provide support for the economic and organizational aspects of the LL, particularly when they are responsible for convening it.

An exploration of sustainability problems in ports requires a holistic understanding and involvement of actors from the quadruple helix—academia, business, policymakers, and society at large (Gerlitz et al., 2024). Citizen and civil society involvement in the co-creation of innovation improves solution inclusivity and quality (Polydoropoulou et al., 2025). This participation is especially important for ports near cities, where externalities like traffic congestion, noise, and air pollution impact citizens directly. Likewise, citizen input is crucial when testing interventions that affect the quality and cost of shipping services (e.g., product and passenger transportation). Therefore, shipping LLs can significantly benefit from the inclusion of civil society organizations or individual citizens in their endeavors. Figure 3 provides a synopsis of the key elements in shipping LLs: the actors involved, the real-life environments used for testing, and the main areas of innovative solutions that are co-created.

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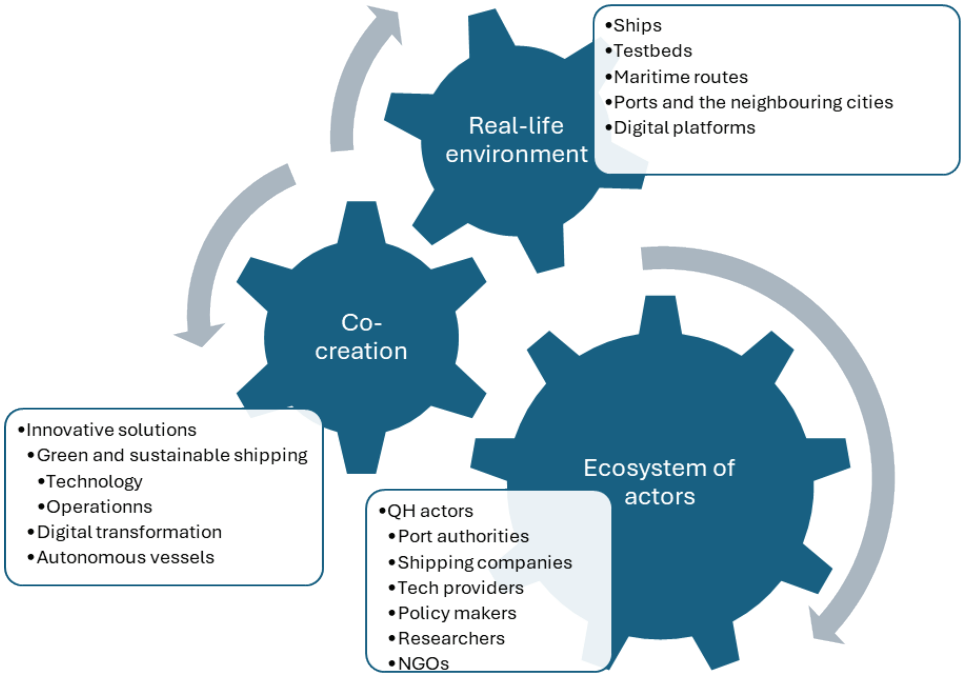

Figure 3. Key characteristics of the living labs in shipping

3.2.3. Scale and complexity:

Living Labs in the shipping industry vary significantly in scale and complexity. Some prioritize developing solutions directly for ships, such as vessel prototypes (FOREMAST, 2025) and onboard automation systems (Bolles and Hanh, 2014) or big data, IoT, and AI to form digital replicas (Kaklis et al., 2023). These LLs often emphasize technical optimization and resemble testbeds, typically involving a limited range of stakeholders. However, many shipping LLs focus on the interactions between vessels and ports, often featuring just-in-time arrival (e.g., MPA of Singapore, n.d.; Valencia Port, 2021) or between ports and their surrounding urban environments (e.g., PIER, n.d.; Kishchenko et al., 2019; 5G-LOGINNOV, 2020; Valencia Port, 2021). Flikkema et al. (2023) employed a Living Lab approach with diverse stakeholders to investigate both digital and non-technological solutions for road, rail, inland waterway, and maritime transport at the Port city of Rotterdam. Their project aimed to have its demonstrators and developments inform the Master Plan for the future European green port.

In addition to ships, ports, and their neighboring cities, small islands (Groppi et al., 2022) and enclosed marine areas like the Baltic Sea (Meškauskienė et al., 2019; Gerlitz et al., 2024) are considered ideal environments for experimentation and innovation, facilitating the replication and scaling-up of successful outcomes. This is particularly valuable in policymaking (Gerlitz et al., 2024), as small-scale trials (e.g., pilot projects) allow for refinements, adaptations, and the exploration of alternative approaches before larger investments in port infrastructure are made. Groppi et al. (2022) characterized small islands as living labs well-suited for testing innovative solutions, such as high Renewable Energy Source (RES) penetration, to generate validated data for mainland replication. Their research revealed that ferries connecting Favignana island (Italy) account for 56% of the island's total energy consumption, leading them to propose ferry electrification using photovoltaic energy. A study by Polydoropoulou et al. (2025) of three Living Labs in Greek Island ports highlights benefits such as accelerated research and innovation, process mapping and validation through stakeholder engagement, risk mitigation via controlled testing, and facilitated knowledge transfer within the port industry ecosystem. Meškauskienė et al. (2019) highlighted the Baltic Sea as a living laboratory for rapidly prototyping and testing solutions ranging from cleaner and safer shipping to remote and autonomous navigation. Furthermore, within the Baltic Sea region, Gerlitz et al. (2024) developed a trans-local LL model to support sustainability transitions in ports through shared governance structures at a macro-regional level. This model enables the enactment of specific sustainability pathways at ports on a micro-scale (local level), with the potential for

scaling them up through trans-local exchange. In summary, Living Labs (LLs) for sustainability transitions offer a platform for experimentation and contribute to achieving sustainability across various sizes, scopes, and scales. This requires careful examination at multiple levels: micro (ship or firm level), meso (port ecosystems), and macro (interventions within regional, national, or global socio-technical systems) (Gerlitz et al., 2024). To function effectively, the larger Living Labs require a diverse ecosystem of participants. Recognizing that these actors may have competing objectives (Polydoropoulou et al., 2025), effective moderation and facilitation become crucial.

3.2.4. Evaluation:

Living Labs (LLs) are a relatively recent development, particularly within the shipping industry. As practical experience accumulates, the scientific literature gradually develops, exploring both the theoretical underpinnings and practical implications. To optimize the allocation of future resources, insights into the evaluation of LL processes and their impact are crucial. As the OECD (2022) notes, process evaluations can enhance public authorities' understanding and management of citizen participation, while impact evaluations determine whether these processes reach their intended audience and achieve their desired effects. However, Paskaleva et al. (2021) suggest that the design, implementation, and reporting of Living Lab evaluations, in general, have received limited attention despite the field's development over the past two decades. This study confirms a similar trend regarding LLs in shipping, which is not unexpected given their relatively recent introduction only a decade ago. To address this gap, funding bodies should consider mandating the evaluation of LL performance and the assessment of their outcomes and impacts (Paskaleva et al., 2021). Meškauskienė et al. (2019) propose three domains (with their respective KPIs) for the evaluation of innovative solutions developed within port LLs: Communication and Documentation of Solution Development, Target Group Outreach and Result Presentation, and Innovation and Sustainability.

4. THE ALIGNMENT OF THE SHIPPING LLS WITH THE SDGS

While the UN's SDGs are often framed at a societal or national level and thus perceived as the responsibility of governments (Delgado-Ceballos et al., 2023), this assumption is flawed. Achieving the SDGs requires a collective effort, and businesses possess the potential, expertise, resources, and a fundamental responsibility to advance global sustainability. Corporate Social Responsibility (CSR) and ESG indicators are key initiatives driving this transformation, shifting the corporate focus from profit alone to a more sustainable approach that prioritizes societal well-being (Delgado-Ceballos et al., 2023). Specifically, living labs in the shipping sector, including those examined in this study, contribute to multiple SDGs and strengthen all dimensions of sustainability: social, economic, and environmental. Table 2 highlights the key SDGs supported by shipping-sector living labs, indicating the number of case studies from this paper that contribute to each goal.

Table 2: The SDGs served by the LLs in shipping

SDG Goal	Shipping LL contribution	Number*
	**SDG 3.** Good health and well-being. LLs in shipping cocreate solutions that reduce port-related pollution in ports and coastal regions, which contributes to the health and well-being of coastal residents.	2
	**SDG 4.** Quality education. Living labs in shipping co-create and test inventive training protocols for practitioners to address the numerous challenges of the industry. Those include the rising technological complexity (autonomous vessels, digital navigation systems, AI and smart port infrastructure), shipping decarbonization solutions, updates in the regulatory regime and the crew diversity and cultural differences.	2
	**SDG 7.** Affordable and Clean Energy. Living labs in shipping promote the development and testing of clean energy solutions for the maritime industry, such as renewable fuels, wind power, and energy-efficient technologies. By reducing reliance on fossil fuels and promoting energy-efficient shipping operations, these labs help drive a transition to cleaner energy sources.	6

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	**SDG 8.** Decent work and economic growth. Living labs in shipping can promote higher levels of economic productivity through diversification, technological upgrading, and innovation, including through a focus on high-value-added and labor-intensive sectors.	7
	**SDG 9.** Industry, Innovation, and Infrastructure. Living labs foster innovation in shipping by experimenting with new technologies such as autonomous vessels, digitalization, and smart shipping systems. These labs can also enhance infrastructure by testing new logistics systems or digital platforms that streamline global shipping operations, improving efficiency and connectivity.	8
	**SDG 10.** Reduced inequalities. The LLs in shipping can adopt approaches to empower racialized groups and reinforce the cooperation between entities from the global north and the global south.	2
	**SDG 11.** Sustainable cities and communities. Shipping is a key part of global supply chains and urban infrastructure. By improving port logistics, reducing shipping emissions, and testing smart city innovations for better integration between shipping hubs and urban areas, shipping living labs can help make cities more sustainable.	5
	**SDG 12.** Responsible Consumption and Production. Shipping is a source of pollution and waste. Living labs can test and implement circular economy practices, such as using sustainable materials, improving waste management, and developing technologies to reduce emissions and fuel consumption.	3
	**SDG 13.** Climate Action. Shipping contributes to global GHG emissions. Living labs can experiment with carbon-neutral technologies, green fuels, and energy-efficient vessels to reduce emissions in the maritime sector. By exploring ways to mitigate climate change through innovative shipping technologies, these labs directly contribute to climate action.	6
	**SDG 14.** Life Below Water. The shipping industry impacts marine ecosystems through pollution and overfishing. Living labs can help develop environmentally friendly shipping technologies that minimize the ecological footprint of the maritime sector. Innovations that reduce pollution and enhance marine biodiversity protection are aligned with this goal.	3
	**SDG 16.** Peace, Justice and Strong Institutions. LLs can support the shipping industry to promote effective institutions to ensure the safe, secure and environmentally protective flow of maritime commerce.	1
	**SDG 17.** Partnerships for the Goals. Living labs, by their definition, bring together a wide range of stakeholders, including governments, industries, research institutions, and civil society organizations. By fostering collaboration and partnerships, living labs contribute to building the partnerships needed to implement and scale sustainable solutions in the shipping industry.	7

**The number of LLs in shipping of this study (out of the 8) that serve the specific SDG*

Living labs in the shipping industry, by definition, are central to advancing SDG 9 (Industry, Innovation, and Infrastructure) through the development of innovative solutions to real-world challenges, thereby fostering economic growth and decent work (SDG 8). Their inherent design allows them to significantly contribute to SDG 17 (Partnerships for the Goals) by creating collaborative ecosystems working towards shared objectives. Furthermore, LLs substantially support SDG 7 (Clean Energy) and SDG 13 (Climate Action) by addressing the urgent need for innovative technologies, fuels, and

operational practices to combat climate change, an effort reinforced by the IMO's new regulations on ship energy efficiency. These decarbonization and clean energy initiatives positively impact the sustainability of coastal cities (SDG 11), while the focus on environmental challenges promotes SDG 12 (Responsible Consumption and Production) and SDG 14 (Life below Water). As a side effect, the good health and well-being of the coastal communities is improved (SDG 3).

The success of these sustainability initiatives depends on continuous workforce education and training in digital skills, alternative fuels, and new technologies (SDG 4). Because shipping is an industry that connects people from diverse backgrounds, interventions promoting the reduction of inequalities (SDG 10) are particularly valuable, including facilitating women's access to jobs within the sector. Recognizing the complex structure of shipping as a global economic activity, reinforcing effective institutions is paramount to ensuring the safe, secure, and environmentally responsible flow of maritime commerce (SDG 16). Additionally, broadening and strengthening the participation of developing countries in the institutions governing shipping is crucial, given their significant representation among ship-building, flag, and ship-recycling states and within the shipping workforce (SDG 16).

Collectively, these efforts cultivate a more sustainable, innovative, and responsible maritime industry, contributing to overall global sustainability.

5. CONCLUSIONS

Living Labs (LLs) are designed to foster innovation through collaborative co-creation. This study explored the scientific and professional literature to identify LLs operating within the shipping industry. Eight cases were selected based on predefined criteria. The aims, structure, and alignment with the UN Sustainable Development Goals (SDGs) of these shipping-related LLs were then analyzed and discussed, drawing on both their observed characteristics and existing scientific literature.

Living labs have emerged in the shipping industry over the last decade, with most initiatives launching within the past six years. These LLs primarily operate in countries of the Global North, particularly in Europe, reflecting the EU's efforts to promote citizen and stakeholder engagement in policy, research, and innovation. Similar interventions could potentially benefit countries in the Global South, which currently hold a significant share of shipbuilding, flagging, ship dismantling, and maritime workforce.

Shipping living labs concentrate on developing innovative solutions and systems. These initiatives are typically led by academia and industry, with testing conducted within ports and shipping companies and regulatory compliance overseen by policymakers. The stakeholders involved in the eight LLs under study include port authorities, shipping companies, technology providers, policymakers, researchers, and academics. Consequently, these LLs largely adhere to the Triple Helix model of innovation. Incorporating civil society representatives, thereby applying a Quadruple Helix (QH) model, could be particularly beneficial, especially in interventions that directly impact people's lives. Examples include the adoption of alternative fuels (which may affect transport costs), actions at ports and coastal areas (influencing congestion, air/water quality, and noise levels), the development of digital apps for seamless transport, and adaptation measures. In general, citizen input in port and coastal shipping interventions would be valuable. Furthermore, public participation would raise awareness and increase acceptance of potentially radical measures, particularly those needed for shipping decarbonization.

Although the application of living labs in shipping is relatively recent, and they often emphasize technological innovations in shipping digitalization and decarbonization, these entities contribute to several UN Sustainable Development Goals (SDGs). Fundamentally, LLs inherently support SDG 9 (Industry, Innovation, and Infrastructure) by generating innovative solutions to real-world challenges. By their very nature, they also foster collaboration among diverse stakeholders, creating a cooperative ecosystem that aligns with SDG 17 (Partnerships for the Goals).

The environmental SDGs primarily addressed are SDG 13 (Climate Action) and SDG 14 (Life Below Water), reflecting the IMO's regulatory framework focused on energy efficiency and various types of onboard waste (e.g., oil, scrubber water). A range of socioeconomic goals, including SDG 7 (Affordable and Clean Energy), SDG 8 (Decent Work and Economic Growth), and SDG 11 (Sustainable

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Cities and Communities), further complement the multifaceted activities of shipping LLs.

The UN SDGs can serve as a comprehensive framework for evaluating new measures in shipping across different dimensions (environmental, social, economic) and balancing outcomes to ensure sustainability. For instance, decarbonization measures (SDG 13) should be subsidized to avoid hindering maritime trade, an economically vital mode of transport that particularly supports developing economies (SDGs 1, 2, and 8).

Given the nascent nature of living labs in shipping, a gap exists in the literature regarding the assessment of their actual impact. As experience accumulates, it is expected that this gap will be filled with valuable insights into how effectively LLs deliver tailored and innovative solutions to real-world challenges. Such studies will be crucial for optimizing resource allocation, streamlining processes, and identifying areas for improvement. To this end, specific Key Performance Indicators (KPIs) that are aligned with the UN Sustainable Development Goals (SDGs) should be established. It is recommended that impact evaluation be an integral component of all shipping LL processes required by their funding agencies. Efficient LL processes, once validated, will be multiplied in the shipping industry, thereby contributing to its overall sustainability.

The examination of Living Labs within the shipping industry highlights their potential to drive collaborative innovation and address sustainability challenges through multi-stakeholder engagement. This enriches the broader discourse on living labs by illustrating how these initiatives facilitate the implementation of UN Sustainable Development Goals in maritime contexts while also underscoring the importance of ongoing evaluation and inclusive participation to enhance the effectiveness and relevance of innovative solutions.

This study is limited by its reliance on desk research, drawing information solely from professional and scientific literature. Future research should incorporate in-depth examinations of real-world living labs in shipping, including interviews with organizers, facilitators, participants, and beneficiaries. This further research could illuminate whether measurable impacts have occurred since the establishment of the labs and whether they have continued or expanded beyond the initial project funding. This would provide a more realistic and comprehensive understanding of the subject. Given the nascent state of the field, further assessment will offer crucial insights into LL design, implementation, and early outcomes, benefiting the entire shipping community.

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