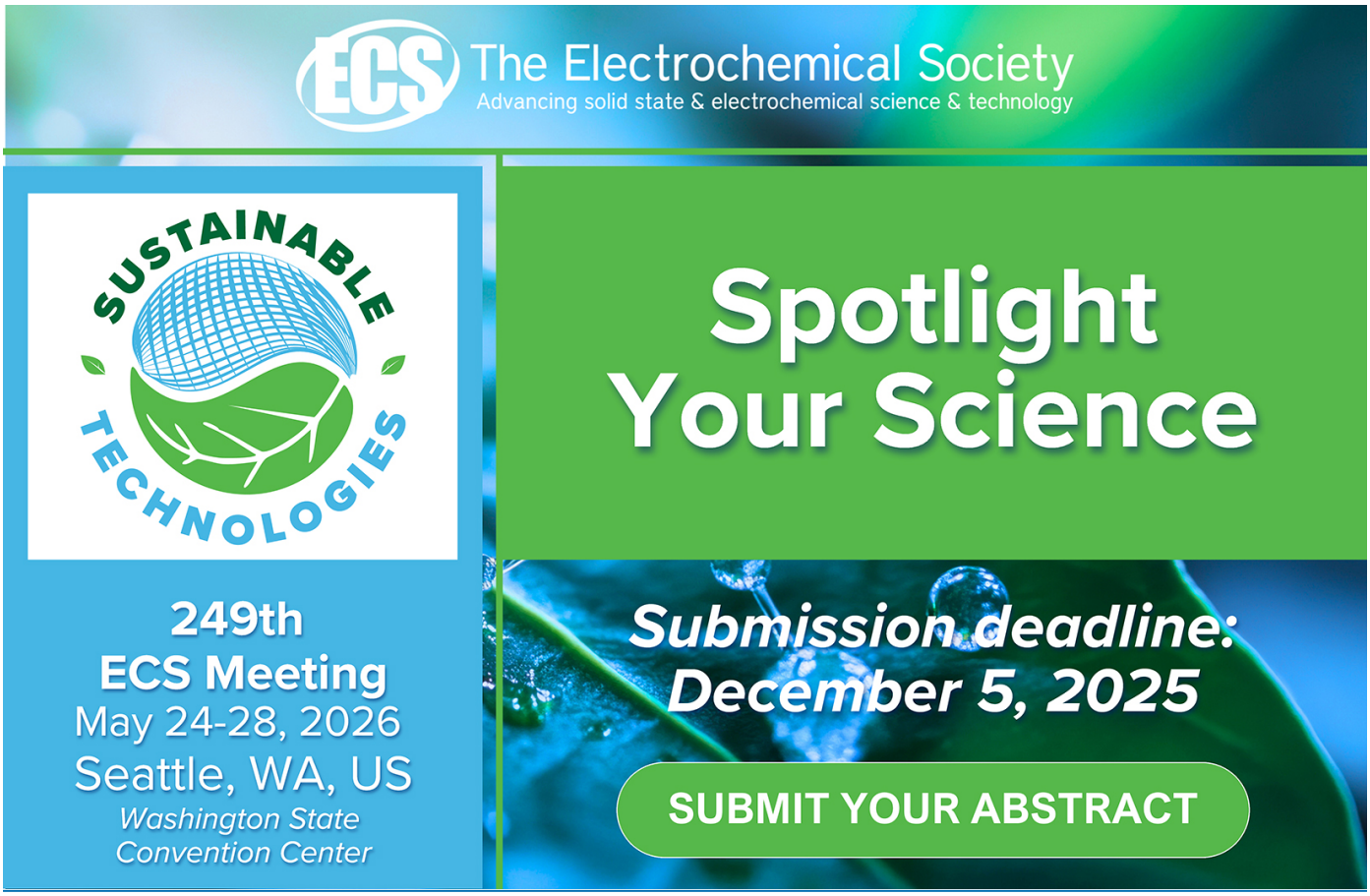
Autonomous Ships in Optimized Logistics Ecosystems: Strategic Models and Survey Insights



Autonomous Ships in Optimized Logistics Ecosystems: Strategic Models and Survey Insights

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Abstract. The emergence of autonomous maritime transport marks a transformative shift in the shipping industry, offering enhanced safety, cost efficiency, and environmental sustainability. However, the integration of autonomous ships into existing logistics chains presents complex challenges, particularly in terms of viable business models. This paper addresses this gap by analysing current and emerging business models through a comprehensive survey and a set of interviews to experts in this topic conducted within the SEAMLESS project. The study identifies key drivers and barriers to adoption, evaluates Cost-Benefit assumptions, and explores interactions with ports and inland waterways. Findings aim to inform EU policy and support the development of resilient, automated logistics services. The results highlight the urgent need for innovative, adaptable business models to ensure the successful deployment of Maritime Autonomous Surface Ships (MASS) in real-world logistics ecosystems.

Keywords: Autonomous maritime transport, Business Models, Logistics Chains, innovation pathway, economic sustainability, SEAMLESS Project, autonomous ship and ports.

1. Introduction

The rise of autonomous maritime transport represents a significant technological advancement with the potential to fundamentally transform the shipping industry. Despite the promising prospects, there is a notable gap in the current literature regarding the formulation and implementation of business models for autonomous ships within logistics chains. This paper aims to bridge this gap by providing a comprehensive analysis of the current state of business models in autonomous maritime transport and exploring future developments.

Autonomous ships, featuring advanced navigation and control systems, offer numerous benefits such as increased safety, lower operational costs, and better environmental sustainability. However, integrating these vessels into current logistics chains poses significant challenges. The complexity of maritime logistics, along with regulatory, technical, and economic barriers, requires a thorough analysis of identified business models to support the adoption of autonomous ships.

Within the framework of the SEAMLESS project, a comprehensive survey has been conducted to extensively explore and analyse the current state of business models in autonomous maritime transport. This survey aims to identify models that align with sectoral needs and investigate future developments within organizations. The insights gained from this survey will inform recommendations to the European Union, supporting the innovation pathway for automated services and clarifying uncertainties regarding their deployment in the maritime, port, and inland waterway sectors. A set of ad-hoc dedicated interviews with companies developing business models related to these logistics ecosystems also will shape the maturity level and penetration into the market of solutions in the sphere of MASS and Logistics and complementing the survey results.

The importance of exploring emerging business models for the adoption of autonomous ships in real logistics chains cannot be overstated. As the maritime industry evolves, understanding and developing these models is crucial for ensuring the seamless integration of autonomous ships into existing logistics frameworks. The survey addresses business models for autonomous maritime transport, their interaction with ports, and future developments, highlighting the need for innovative approaches to overcome current challenges.

From the perspective of current situation analysis and future trends, the survey conducted an in-depth analysis of the principal barriers or challenges to implementing business models for autonomous ships and ports. It also identifies the top five factors driving the development and adoption of these models within the port-maritime sector. By focusing on these critical aspects, the survey underscores the significance of developing robust business models that can facilitate the widespread adoption of autonomous ships, ultimately leading to enhanced efficiency, safety, and sustainability in maritime logistics.

The SEAMLESS project [1] aims to develop and adapt essential technology building blocks and key enabling technologies to create a fully automated, economically viable, cost-effective, and resilient waterborne freight feeder service for Short Sea Shipping (SSS) and Inland Waterways Transport (IWT). Autonomous systems will be pivotal in ensuring safe, efficient, and environmentally friendly operations, facilitating the transition of road freight movements to hinterland waterways.

The structure of the paper will comprise a brief literature overview, followed by a detailed methodology section emphasizing the qualitative and quantitative design and implementation of both the survey and the interviews performed. The results section will present the key findings, highlighting complementary insights derived from the interviews and finally, the paper will include a section with short conclusions.

2. Literature overview on business models

Although the development of Maritime Autonomous Surface Ships (MASS)[2] has progressed significantly in recent years, most existing studies have focused on technical, operational, and regulatory aspects. In contrast, business models associated with this type of transport have received much less attention, despite being a key element for real integration into logistics chains.

Some works, such as Munim (2019) [3], point out that although autonomous ships offer advantages in terms of efficiency and sustainability, it is still unclear how economic value can be generated from their use. The author highlights that most current initiatives are still in pilot

phases, and that new business model approaches—beyond simply selling or leasing vessels—need to be explored in greater depth.

Similarly, authors such as Ziajka-Poznańska and Montewka (2021) [4] emphasise the current uncertainty surrounding the real costs, benefits, and value creation potential of MASS. These studies point out that elements such as investment requirements, crew cost reduction, system maintenance, cybersecurity risks, and integration with logistics operations are all key challenges for business model development. They also suggest that MASS will only create real market opportunities if value is generated not only for shipowners, but also for technology providers, ports, and remote operation centres—through collaborative and ecosystem-based approaches.

In summary, the literature agrees on the need to develop innovative, sustainable, and adaptable business models that respond to real-world challenges in the maritime sector. However, there is still a lack of empirical studies that assess market readiness, stakeholder acceptance, and long-term profitability. This paper aims to help fill that gap by analysing data gathered through a survey and experts interviews conducted under the SEAMLESS project.

3. Methodology

The primary objective of this study is to conduct a comprehensive analysis of the current state of business models applied to autonomous maritime transport, with the aim of identifying those models that present viable alternatives aligned with both the present and anticipated future needs of the sector. Furthermore, the study seeks to explore potential organizational developments that may support the adoption and scalability of these emerging approaches.

The insights derived from this analysis will inform a set of strategic recommendations to be submitted to the European Union, thereby contributing to the innovation pathway necessary for the effective deployment of automated maritime services. These contributions are intended to reduce uncertainty and facilitate the integration of autonomous solutions across maritime, port, and inland waterway systems.

The methodology employed in this study is outlined in the following diagram:

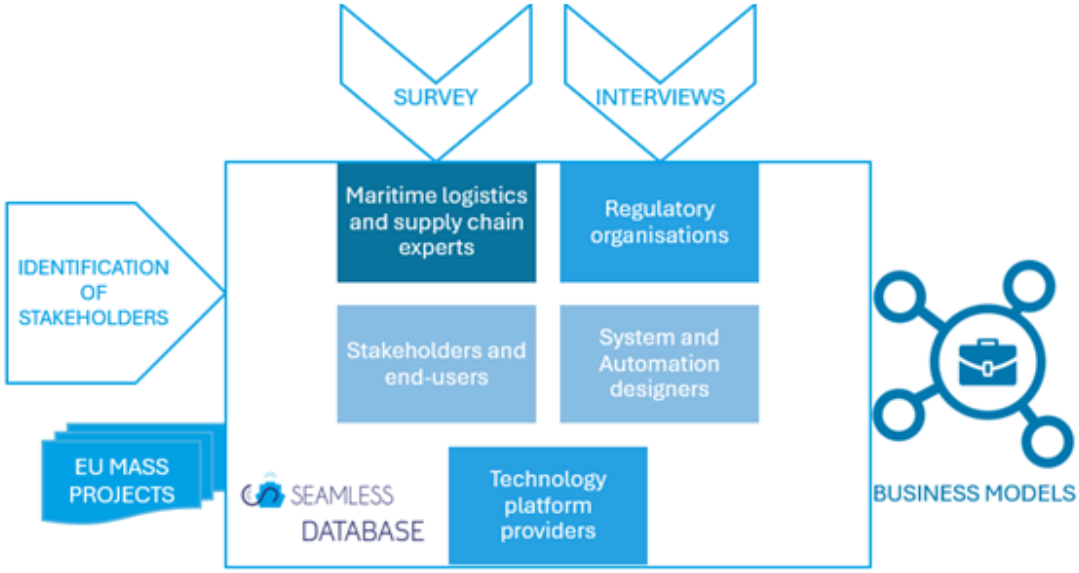

Figure 1. Methodology approach used in the study. Source: Own elaboration

To gather empirical evidence, a structured survey was disseminated through multiple channels, leveraging a purpose-built database specifically developed for this study. The survey engaged over 436 companies spanning the maritime logistics ecosystem related to MASS. Data collection was conducted between May 2024 and January 2025, with an extension granted in January to allow additional entities to participate and further enrich the dataset.

The selection of companies was conducted through an in-depth analysis of the actors potentially affected by the adoption of autonomous maritime transport within the supply chain. This process involved consulting a variety of sources to identify relevant companies and entities operating in the field. A structured classification of companies/entities/Experts was developed, encompassing the following categories:

- Maritime logistics and supply chain experts – 60 entities
- Regulatory organizations – 43 entities
- Stakeholders and end-users – 199 entities
- System and automation designers – 70 entities
- Technology platform providers – 64 entities

To complement the analysis, a detailed examination of the geographical distribution of companies was conducted. Out of the 436 respondents, 75 are based in the United Kingdom, 61 in Norway, 48 in Germany, and 45 each in Belgium and Spain. Additional representation includes 28 stakeholders from France, 23 from the Netherlands, and 16 from the United States. The dataset is further enriched by contributions from Finland, Denmark, Greece, and Italy, reflecting a broad European and transatlantic engagement with the topic. It is highlighted that Europe concentrates a lot of companies/entities/experts working or interested in this matter.

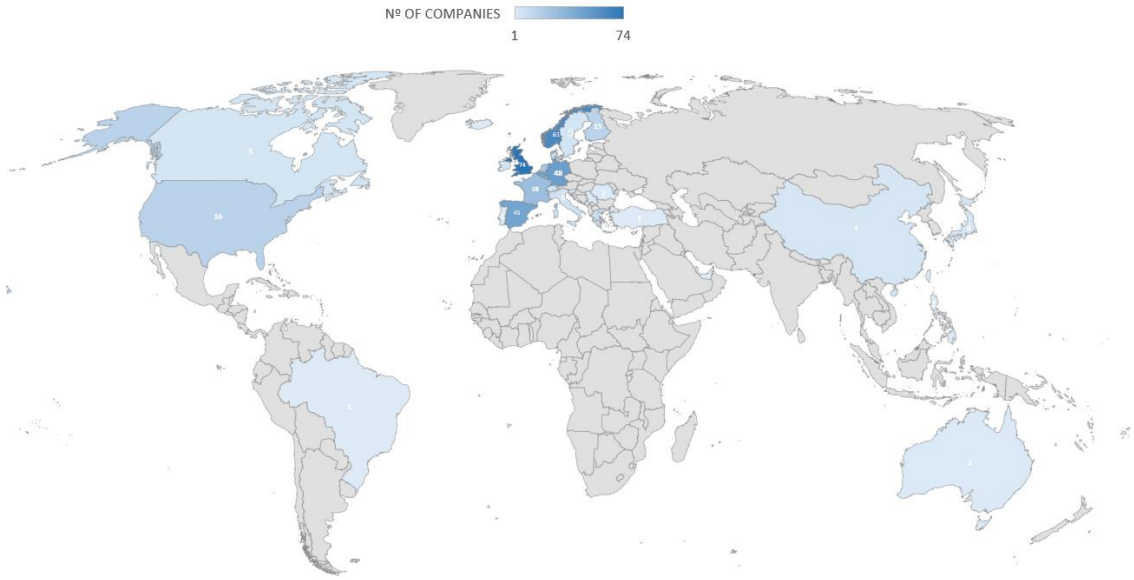

Figure 2. Geographical distribution of stakeholders. Source: Own elaboration using Bing tool.

To maximize response rates and ensure broad representation, the survey was disseminated through multiple channels. These included targeted LinkedIn groups focused on autonomous shipping, outreach to key individuals, and collaboration with coordinators and partners from EU-funded projects related to Maritime Autonomous Surface Ships (MASS), such as AUTOSHIP[5], AEGIS[6], MOSES[7], FOREMAST[8], and AUTOFLEX[9]. Additional dissemination was carried out through national and local initiatives worldwide, as well as other LinkedIn groups dedicated to maritime and port sectors.

The survey was designed to be completed in approximately 20 minutes and comprised 23 questions. It included a combination of multiple-choice items to facilitate rapid responses and open-ended questions to capture case-specific insights. The structure of the survey is outlined as follows:

- Introduction – it provides information about data protection, confidentiality and how to manage info about the responder in the frame of SEAMLESS project.
- Registration and contact details – It includes personal data on the responder´s profile and the type of organization they are representing.
- Business models information – it collects information on the relevant business models information at company level and developments in ongoing or future models.

- Analysis of the current situation and future trends – It provides information on the main barriers or challenges and possible drivers for the development and adoption of business models.
- Additional information – It includes additional information freely provided by the respondent and a possible interview.

To complement the insights obtained from the survey responses, a comprehensive interview protocol was developed. The formulation of the interview questions was guided by the objective of addressing thematic areas and analytical dimensions that may not have been fully captured through the survey instrument. Accordingly, fourteen ad hoc questions were designed, specifically focused on business models and aligned with the structural framework of the survey. These questions aimed to elicit deeper qualitative insights and contextual nuances from selected stakeholders. The questions are as follows:

1. Could you please introduce yourself and tell us a bit about your background, experience, and what brought you to this project? Name, company and position.
2. Could you elaborate on your organization's involvement or relationship with autonomous shipping? The idea is to describe your involvement or role in relation to autonomous ships within your organization and the level of contribution in these kinds of initiatives.
3. How can autonomy contribute to addressing the key challenges faced by the maritime industry, such as sustainability and crew shortages?
4. What strategic goals or benefits does the organization aim to achieve through the integration of automated technologies in the maritime industry?
5. Are there any expected changes to the business model or operational processes (e.g., logistical processes, organization, digital tools) as a result of adopting autonomous transport?
6. What are the main barriers or challenges that your company identifies when developing automation in ships?
7. Are there strict operational requirements in your company that cannot be altered, and to which autonomous transport services would need to adapt?
8. How does the organization address or plan to overcome these challenges in the process of implementing autonomous shipping?
9. What kind of benefits or value would your organization need to see or expect to see to make significant changes to your current business model or operations to adopt autonomous shipping?
10. How important is collaboration within and potentially outside the organization when implementing automation shipping?
11. To what extent do regulatory considerations and financial aspects impact the development and implementation of solutions related to ship automation?
12. Could you please explain your business model? How does your organization generate revenue and create value for its stakeholders?
13. What risks is your organization willing to take when adopting autonomous shipping technologies? What is the main pain points you seek to mitigate through these technologies?
14. Is there any question you feel has not been addressed, or anything else you would like to add on this topic?

In conclusion, the findings derived from the survey and the complementary interviews offer a robust and multidimensional analysis of business models related to autonomous shipping and

logistics within the global maritime and port sectors, with particular emphasis on their prospective market adoption and scalability.

4. Results

This section presents a summary of the main descriptive findings derived from the survey, offering an analytical interpretation of the results and highlighting key insights. In addition, a selection of significant findings from the interviews is included to enrich the analysis. A comparative overview of both methodological approaches is also provided.

In the introductory phase, the following key outcomes were observed: the database developed for this study comprised 436 companies, which were contacted through various dissemination channels. A total of 81 responses were received, of which 75 were validated and accepted. In six cases, multiple individuals from the same organization submitted responses. These instances prompted follow-up discussions with the respective companies to consolidate the inputs into a single, coherent response per entity. This process ensured that no relevant information was lost and that the final dataset accurately reflected each organization's position. Notably, 84% of participants expressed their willingness to continue receiving updates related to the project.

Regarding the size of the organization, 32 of the participants belong to a Large enterprise (more than 250 workers), 25 of the participants belong to a Small enterprise (1-50 workers) and finally 18 of the participants work in medium enterprise companies (51-250 workers).

Regarding the type of organization of the participants, it is stated that a diverse range of organizations that participated in the survey, with a notable concentration in the maritime and research sectors. The most prominent group is "Maritime solutions/manufacturers," contributing 17 responses, underscoring the strong involvement of companies focused on maritime technologies and production. This is followed by "Research organisations/research centres" with 12 responses, reflecting active engagement from the scientific and innovation community. Both "Other Public Administration" and "Shipping companies/Shipowners/Ship managers" each provided 8 responses, indicating significant interest from governmental bodies and maritime transport operators. Additionally, "Classification societies/Insurance companies," "NGOs," and "Universities" each contributed 7 responses, showing a balanced representation from regulatory, civil society, and academic institutions.

The remaining categories, such as port service providers, governmental maritime authorities, healthcare providers, training institutes, technology providers, and maritime associations, each had between 1 and 3 responses. This suggests broad but less concentrated participation from specialized and supporting stakeholders across the maritime ecosystem.

The following subsection provides an analysis of the participants' profiles. The bar chart illustrates the distribution of individuals across various professional roles. The most represented position is "Head of Projects/Manager," with 19 individuals holding this title, closely followed by "Principal Consultant/R&D Project Manager," which accounts for 18 individuals. Several roles share the same number of representatives, including "Senior Adviser," "Researcher," and "CEO - Founder," each with 7 individuals. 6 people hold the role of "Director", while "Professor" appears 4 times. Less common roles include "Applications Engineer" with 3 individuals, "Lecturer" with 2, and both "Secretary General" and "Board Member" with just 1 individual each. This distribution highlights a strong presence of leadership and consultancy roles within the group.

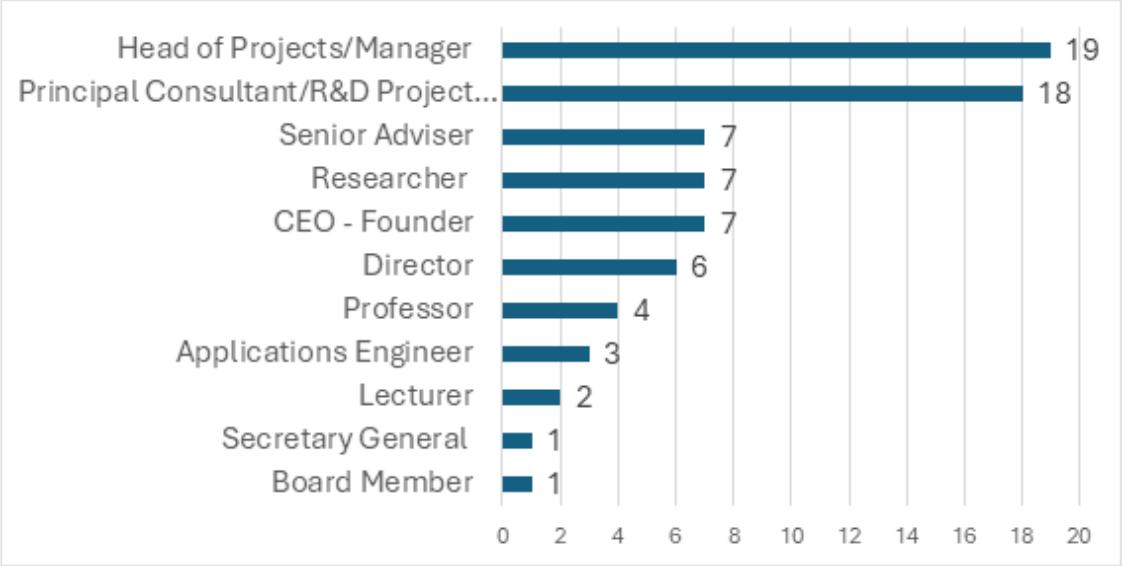

Figure 3. Participants' profiles of the survey. Source: Own elaboration

The profile of the survey participants also provides valuable insights into the strategic relevance of autonomous shipping within their respective organizations. A total of 79% of respondents indicated that autonomous shipping is considered a strategic topic. In terms of experience, the majority of companies (36.5%) reported having between three and five years of involvement in this field, followed by 27% with zero to two years, 23% with six to eight years, and 13.5% with more than eight years of experience. Furthermore, 81% of respondents confirmed the presence of dedicated personnel or teams working on autonomous shipping within their organizations.

Among those organizations, the majority reported small teams of one to three individuals assigned to this area. Only 18% indicated having teams of more than ten people, a figure that corresponds primarily to larger companies. From a Research, Development, and Innovation (RDI) perspective, 37 out of 74 respondents that replied, confirmed the existence of an approved annual budget specifically allocated to autonomous shipping initiatives.

Gathering information on business models proved to be particularly challenging, given the competitive sensitivity surrounding market strategies, value propositions, and competitor monitoring. Nevertheless, the survey revealed that 26 out of 74 companies reported having a business model for autonomous ships, without specifying alignment with the different degrees of

autonomy defined by the International Maritime Organization (IMO). Among the 41 companies that indicated they do not currently have a business model, 14 reported ongoing efforts to develop one. In total, 40 out of 74 respondents—representing 54%—are actively engaged in the development of business models for autonomous maritime operations.

In this context, the interviews revealed that individuals working on autonomous shipping issues are often involved in international working groups that address the full spectrum of autonomous vessel implementation. While many interviewees represent private sector organizations, it became evident that addressing business model development requires a broader understanding—beginning with regulatory frameworks and extending to deep sectoral knowledge of maritime and port operations. In particular, the insights of professionals with seafaring experience were highlighted as essential for identifying operational processes that could justify the adoption of autonomous solutions.

With regard to business model information, the main findings relate to current developments, ongoing initiatives, and anticipated future models. Notably, 38% of participants expressed interest in studies focused on business model frameworks. These interests can be categorized into four principal thematic areas:

- The Economic and Financial Dimension of Autonomous Maritime Operations:This part highlights the need for sustainable cost structures and investment models. It covers operational costs such as training, compliance, maintenance, and software, while also exploring innovative financing methods like leasing, vessel stock-building, and buy-back guarantees.
- Business Models and Ecosystems: This area addresses the transformation of maritime logistics through autonomous technologies. It explores how business models interact within the autonomous shipping ecosystem, the competitive edge of autonomous solutions over traditional transport, and innovation in supply chains. It also considers the role of short sea shipping in ecosystem development, market structures, pricing strategies, Remote Operations Centres (ROCs), and the integration of new models into existing logistics frameworks to create value.
- Autonomous Maritime Systems and Operations: This section focuses on the technological and operational domains where autonomy is most impactful. It includes smart maritime systems such as remote control, autonomous navigation, and decentralized cargo handling, applied across various transport modes like deep-sea, inland, urban, and port operations.
- Alternative Energy: Autonomous shipping is seen as a key enabler of decarbonization, with growing integration of alternative fuels and clean propulsion technologies. These advancements support environmental goals and foster innovation-driven competitiveness in the maritime industry.

In alignment with the insights gathered from the interviews, it is evident that companies prioritize business models that address concrete operational challenges. The mere application of technology, without a clear problem-solving orientation, is perceived as insufficient in a sector as traditionally structured as maritime transport. From an ecosystem perspective, early adopters of autonomous solutions may gain a competitive edge over those adhering to conventional shipping practices. However, the complexity of the maritime logistics ecosystem—where collaboration is essential—demands that any viable business model be mutually beneficial.

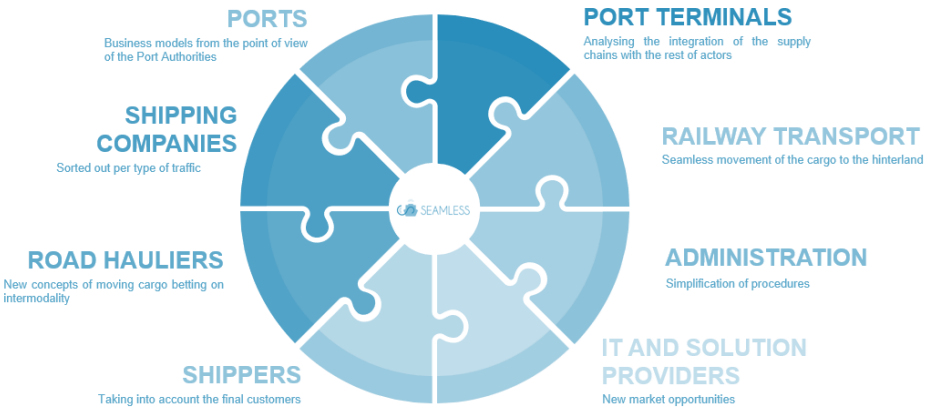

Figure 4. Analysis of Stakeholders impacted by Business Models on Autonomous Shipping and logistics. Source: Own elaboration

Innovation, particularly when applied to the supply chain through advanced technologies, must reinforce the business case by enhancing market positioning and optimizing operational performance. Value creation is increasingly associated with the integration of intermodal transport operators, enabling the development of robust and sustainable business models. The logistics sector tends to reject technologies that do not directly support supply chain efficiency or improve service to end customers, viewing transport primarily as a means to an end rather than an end in itself.

The internalization of costs associated with technologically advanced units is a critical consideration. This includes training, lifecycle maintenance of both hardware and software, and the integration of systems—both upstream and downstream—to ensure compatibility with existing supply chain operations. While promising economic returns may underpin the financial rationale, the initial phases of adoption often rely on public funding mechanisms such as grants and subsidies to catalyze the transition. From an environmental perspective, interviewees underscored that autonomous shipping solutions are significantly more compelling when they are explicitly aligned with broader sustainability objectives. These include measurable reductions in fuel consumption and greenhouse gas emissions, improvements in navigational safety, and the mitigation of onboard operational risks.

Furthermore, the section addressing the current state of the sector and anticipated future developments provides critical insights into the principal barriers and enabling factors

influencing the adoption and implementation of business models for autonomous vessels and port systems. These subgroups are:

- Underdeveloped Technology: Obstacle arising when the necessary technology for implementing autonomous ships has not reached a level of development adequate to ensure efficient and safe operation.
- Legal and Regulatory Issues: Challenge stemming from the lack of clear legal frameworks and regulations that can guide and support the operation of autonomous ships, creating uncertainty and potential legal conflicts.
- Cultural Resistance and Lack of Trust: Barrier related to the reluctance of individuals and maritime communities to accept and trust autonomous technology, potentially hindering its widespread adoption and acceptance.
- High Implementation Costs: Financial challenge arising when the substantial costs associated with the introduction and maintenance of autonomous systems in ships pose an obstacle to their widespread implementation in the maritime industry.
- Environmental Barriers: Challenges related to environmental concerns, such as the impact of autonomous ships on ecosystems, emissions, and sustainability.
- Training and Professional Profile: Obstacles arising from the need for training and development of maritime professionals to adapt to and operate autonomous systems, along with potential challenges in finding individuals with the suitable professional profiles for these roles.

The bar chart illustrates the perceived relevance of various barriers that could hinder the implementation of business models for autonomous ships and ports, based on respondents' rankings. The most significant challenge identified is Legal and Regulatory Issues, which received the highest level of concern. This reflects widespread uncertainty due to the absence of clear legal frameworks and regulations to support autonomous maritime operations. Underdeveloped Technology was ranked next, indicating that current technological capabilities may not yet be sufficient to ensure safe and efficient autonomous operations. Underdeveloped technology remains a significant barrier to the adoption of autonomous ship business models. Despite growing interest, current technological capabilities often fall short in areas such as real-time decision-making, sensor integration, and cybersecurity. Following closely is High Implementation Costs, highlighting the substantial financial investment required to adopt and maintain autonomous technologies.

Cultural Resistance and Lack of Trust also emerged as a key barrier, pointing to scepticism and reluctance within the maritime community toward embracing automation. Additionally, Training and Professional Profile challenges were noted, emphasizing the need for new skill sets and professional development to support this transition. Lastly, Environmental Barriers were considered the least critical, though still relevant, encompassing concerns about ecological impacts and sustainability.

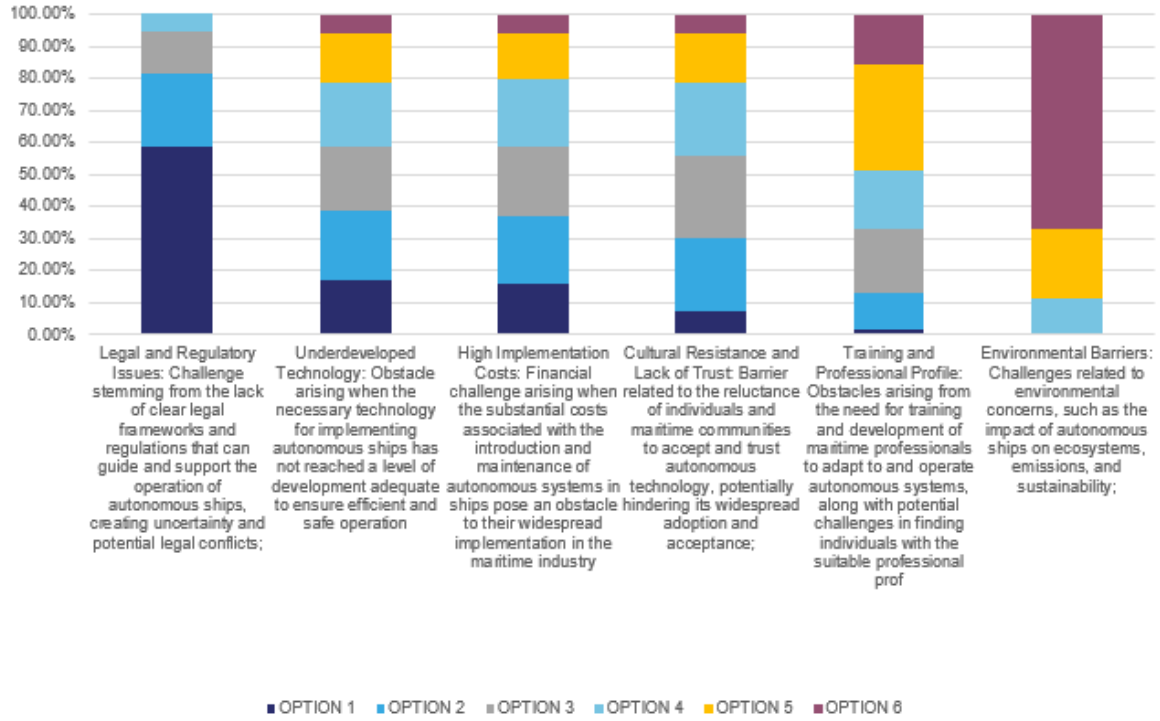

Figure 5. Ranking of principal barriers and enabling factors influencing the adoption and implementation of business models for autonomous vessels and port systems. Source: Own elaboration

Beyond the ranked barriers and broadening the spectrum of barriers, several others have been collected. The implementation of autonomous maritime systems faces several challenges, particularly regarding safety and operational readiness. While having crew onboard can support maintenance and emergency response, concerns remain about designating responsible personnel for Search and Rescue operations. Investment levels—both public and private—are currently insufficient, and the absence of a unified global strategic approach further hinders progress. Regulatory barriers, especially the lack of standardized risk assessment methods, increase costs and uncertainty. Industry conservatism also slows adoption, suggesting that MASS (Maritime Autonomous Surface Ships) should be positioned as practical solutions rather than disruptive innovations. Additionally, the complexity of different systems demands extensive operator knowledge, emphasizing the need for user-centered design. Organizational transformation is essential, yet certification processes for safety-critical systems remain unclear, and challenges persist in standardizing connectivity, workplace transitions between Remote Operations Centres (ROCs), and automating onboard units beyond navigation.

Business models in autonomous shipping are typically shaped by national legal frameworks, as their innovative nature and complex adoption make local implementation more practical than international deployment. These models involve high upfront costs and require incentives to be viable, with benefits needing to outweigh significant operational expenses. Without integration into land-based logistics, the models remain overly complex and offer limited advantages.

Technological development often targets localized use cases, necessitating a gradual, cost-controlled approach to deployment. Interviews highlight that financial viability depends on applying only essential technologies, as premature experimentation can delay reaching the Technology Readiness Level (TRL) needed to attract investment.

Not only are the barriers to adopting business models around autonomous ships important but identifying the specific factors that effectively drive the development and adoption of the business model in question is also particularly relevant. In this regard, eight specific factors were selected, and participants were asked to rank them by level of importance. Those specific factor were:

- Technology, processes, design, standards and infrastructure: Factors associated with significant advancements in autonomous technology, such as sensor systems, artificial intelligence, and navigation capabilities.
- Rules, policies and regulatory instruments: Key factors related to enable regulations and legal frameworks that provide clarity, guidance, and support for the safe and effective integration of autonomous ships into maritime operations.
- Cost-effectiveness: Factors related to the cost-effectiveness of autonomous technologies, including reduced operational costs, efficient fuel consumption, and potential economic benefits, which can incentivize the adoption of autonomous ship.
- Fiscal instruments and financial investment and funding: Mechanisms related to financial incentives, investments, and funding that can drive the development and implementation of autonomous ship technologies.
- Collaborative environment: Drivers involving collaboration and partnerships within the maritime industry, fostering the exchange of knowledge, expertise, and resources to accelerate the development and adoption of autonomous ships. It serves as a kind of 'physical' playground for testing.
- Knowledge, skills and capabilities: Factors related to the development of necessary knowledge, skills, and capabilities in the workforce for the effective operation and maintenance of autonomous ships.
- Awareness and information regarding autonomous ship: Initiatives focused on increasing awareness and providing information to stakeholders about the benefits, risks, and advancements in autonomous ship technologies.
- Market uptake: Strategies and mechanisms that drive the acceptance and integration of autonomous ships in the market, including market demand, and widespread adoption trends.

The result was that Rules, policies and regulatory instruments were the most important set of factors from the point of view of the responders, followed by Cost-Effectiveness factor, the Technology, processes, design and standards and infrastructure and market uptake. The less interesting from the point of view of the responders was the collaborative environment, the knowledge, skills and capabilities and the awareness and information regarding autonomous ships. Several elements were highlighted in the section on key opportunities in terms of new services, potential markets and other innovative aspects.

Autonomous fleet management is becoming central to future maritime operations, offering services like dynamic routing, logistics optimization, and predictive maintenance. These innovations enhance efficiency and reduce downtime by using real-time data and analytics,

enabling more responsive and cost-effective operations. Business models should be approached from a multilateral perspective, considering opportunity costs and labor shortages, such as the lack of dockworkers. Interviews suggest that remote and autonomous ship operations, along with simultaneous monitoring of multiple vessels and automation of manual tasks, present key opportunities for new services and market niches. Autonomy in maritime transport is expected to improve safety, reduce human error, and lower operational costs, while also creating new job roles in remote operations and system maintenance. Innovations like centralized booking, USV classification, and ferry-on-demand services are transforming short sea transport. However, the need for highly specialized professionals and viable incentive schemes remains a challenge. Economically and environmentally, autonomous technologies offer benefits such as reduced insurance costs, lower CO_2 emissions, and safer navigation. Small electric vessels and efficient feeder services support urban and short sea transport. Success depends on new logistics chains, cross-sector collaboration, and inclusive workforce development in remote operations.

In order to evaluate the feasibility of developing business models for autonomous ships and logistics chains, the next figure presents an overall assessment of the impact in the different stakeholders regarding the implementation of these concepts. For that purpose, it has been used DG Regio Methodology.

The DG Regio Cost-Benefit Analysis [10] methodology and the Economic Appraisal Vademecum 2021-2027 [11] provides a structured framework to assess the viability of infrastructure and innovation projects, such as those involving autonomous ships and their supporting logistics networks. It is divided into two main components: financial analysis and economic analysis. Financial analysis focuses on direct monetary flows, evaluating changes in demand, investment needs, operating and maintenance costs, and revenue generation. For autonomous shipping, this could involve assessing the capital costs of vessel automation, reduced crew-related expenses, and potential increases in service frequency or reliability. Economic analysis, on the other hand, captures broader societal impacts. It includes consumer surplus, producer surplus, and externalities such as reduced emissions or noise in port areas. The methodology also considers the effect on market competition, which is particularly relevant as autonomous technologies may lower entry barriers or shift competitive dynamics in maritime transport. Both analyses culminate in the calculation of Net Present Value (NPV) and payback periods, helping stakeholders determine whether the long-term benefits of autonomous shipping outweigh the upfront costs.

The cost-benefit analysis, conducted as an a priori assessment, suggests that shipping companies and ship operators are likely to benefit from increased demand, higher revenues, and reduced maintenance costs, despite requiring greater upfront investment. Port authorities, particularly in relation to nautical services, face increased investment needs but do not show clear financial or economic gains. Terminal operators may experience cost reductions with limited changes in demand or capital expenditure. Shippers and customers are less directly impacted financially but could benefit from improved service quality. However, these results are indicative

and should be refined through case-specific calculations, as actual impacts will vary depending on the operational, geographic, and technological context of each project.

	COST-BENEFIT ANALYSIS COMPONENTS	Definition	Shipping Companies – Shipowners	Ship Operators	Port Nautical Services	Port Authorities	Port Terminals	Hinterland Operators	Shippers - Customers
FINANCIAL ANALYSIS	DEMAND (↑/≈/↓)	Quantification of services compared with business as usual	≈	↑	≈	≈	≈	↑	≈
	INVESTMENTS (↑/≈/↓)	Allocation of resources with the expectation of generating future returns or benefits	↑	↑	≈	↑	↑	↓	↓
	OPERATING COSTS (↑/≈/↓)	Ongoing expenses a business incurs through its normal business operations.	↓	↓	↑	≈	↑	↓	↓
	MAINTENANCE COSTS (↑/≈/↓)	Expenses associated with keeping equipment, machinery, infrastructure, or systems in good working condition	↓	↓	↑	↑	↑	↓	≈
	REVENUES (↑/≈/↓)	Total amount of money a company earns from its normal business activities, usually from the sale of goods and services, before any costs or expenses are deducted	↑	↑	≈	↑	↑	↑	↑
	MAIN RESULTS – NET PRESENT VALUE (+/≈/-)		+++	+++	-	+	≈	+++	++
	PAYBACK (Low/Medium/High)		Low	Low	High	Medium	High	Low	Low
ECONOMIC ANALYSIS	CONSUMER SURPLUS (↑/≈/↓)	Difference between the maximum price a consumer is willing to pay for a good or service and the actual price they pay	≈	≈	≈	≈	≈	≈	≈
	PRODUCER SURPLUS (↑/≈/↓)	Difference between the price a producer receives for a good or service and the minimum price they would have been willing to accept	↑	↑	≈	↑	↑	↑	↑
	GOVERNMENT SURPLUS (↑/≈/↓)	a government's total revenues (mainly from taxes, fees, and other income) exceed its total expenditures over a specific period	↑	↑	≈	↑	↑	↑	↑
	EXTERNALITIES (↑/≈/↓)	unintended side effects or consequences of an economic activity that affect third parties who are not directly involved in the activity	↓	≈	≈	≈	↓	↓	↓
	MAIN RESULTS – ECONOMIC NET PRESENT VALUE (+/≈/-)		+++	+	≈	+	++	+++	+++
	PAYBACK (Low/Medium/High)		Low	Medium	High	Medium	Medium	Low	Low

Figure 6. Cost-Benefit Analysis evaluation for different stakeholders. Source: Own elaboration

5. Conclusions

The integration of Maritime Autonomous Surface Ships (MASS) into optimized logistics ecosystems represents a transformative opportunity for the maritime sector, offering potential gains in safety, efficiency, and sustainability. However, this study confirms that the successful deployment of autonomous shipping technologies is contingent upon the development of viable, adaptable business models that align with both current operational realities and future innovation pathways. Through a comprehensive survey and targeted interviews conducted within the SEAMLESS project, the research identifies critical drivers—such as regulatory clarity, cost-effectiveness, and technological maturity—as well as persistent barriers, including high implementation costs, legal uncertainty, and cultural resistance.

The findings underscore the importance of embedding autonomous solutions within broader logistics chains, supported by collaborative frameworks and targeted financial incentives. Business models must be grounded in real-world operational needs, emphasizing value creation, risk mitigation, and integration with land-based infrastructure. Ultimately, these insights provide a strategic foundation for stakeholders to design scalable, resilient, and economically sound pathways for the adoption of autonomous maritime logistics.

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