Impact of Autonomous Navigation in Short Sea Shipping

Subjects: Transportation

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Short sea shipping (SSS) is a concept created in the European Union (EU), building upon the traditional concept of cabotage, but expanding it to an EU scale and adding maritime connections to countries across seas surrounding Europe. In spite of being a European concept, the fact is that it applies very well to other areas of the world, often under other designations such as coastal shipping or international cabotage.

Keywords: short sea shipping (SSS) ; European Union (EU) ; autonomous navigation ; autonomous ship ; automation

1. Introduction

In Europe, the development of SSS has been less intense, especially when measured against that of road transportation, probably because the land transport infrastructure across the continent is extensive and competitive. Recent events such as the pandemic and the Russia–Ukraine war have not favoured SSS either, especially in the passenger segment [1]. Finally, the need for near-shore production identified in recent years and, thus, to streamline supply chains may well promote some additional development in SSS in the EU over coming years in detriment of deep-sea shipping (DSS).

The competition of SSS with road has been especially difficult as road transport has benefited from lower labour costs due to the influx of eastern European drivers. It also takes advantage of much-improved road transport infrastructure and even benefits from the faster adoption of green technologies, increases in fuel efficiency, and less polluting fuels (lower sulphur content). Maritime transport remains the greener option, carrying between 80% and 90% of the world's freight while emitting only 3% of the world's greenhouse gases [2][3], but recent studies indicate that SSS, in particular, may be losing part of its green advantage, leading to the necessity of applying stricter emissions regulations for SSS to maintain its green image [4][5][6].

Traditionally, SSS has had the disadvantage of being only a connection between ports, rather than a full door-to-door transport operation, putting it at a disadvantage in comparison to road haulage. This is the reason that revision of the combined transport EU directive is much needed [7], as it promotes the development of intermodal and multimodal transport. This recent development comes in the wake of the reaffirmed commitment of the EU to greener modes of transportation, as expressed in the "European Green Deal" communication [8] which pointed to the need to reduce transport greenhouse gas emissions (GHG) emissions by 90% by 2050 to achieve climate neutrality. It has also set an objective for a substantial part of the 75% of inland freight carried today by road to be shifted onto rail and inland waterways. Later, the "Sustainable and Smart Mobility Strategy" established more detailed and comprehensive objectives so that transport by inland waterways and short sea shipping would increase by 25% by 2030 and by 50% by 2050 as compared to the 2015 levels [9].

In order to materialize this shift towards SSS, which is primarily aimed at reducing transport emissions, it is necessary that shipping keeps pace with road transport technology improvements. Electrical batteries are one possible solution as ships engaged in SSS typically operate on short routes near the coastline, making it easier to adopt such propulsion solution, as revealed by a recent China-built 700 TEU (twenty-foot equivalent unit) container vessel [10]. Alternative greener fuels suitable for internal combustion engines may also be adopted, but at the moment there is a scarcity of such fuels in the market and this constitutes a barrier to their widespread adoption. In this context, the inclusion of SSS in the emission trading scheme (ETS) [11], a typical market-based measure (MBM), will come as an additional burden as alternative fuels are not readily available, leading to extra costs and potentially promoting a reverse modal shift to road transport.

The International Maritime Organization (IMO) has privileged goal-based measures (GBMs) such as the application of carbon intensity indicators (CII) [12][13]. These will heavily impact the short sea fleet because they are based on ship operations and SSS is characterized by short routes and comparatively long port times, reducing the ship's ratings. The effectiveness of MBMs vis a vis GBMs has recently been compared and discussed in [14]. Additionally, the intention of the EU to remove the tax exemption on marine fuels by adapting the EU energy taxation directive in 2023 will increase voyage costs [15].

In spite of these difficulties, the fact remains that SSS could have a determinant role in reducing transport industry externalities. It is well known that transport activities impose costs on society and the environment that are not fully taken into consideration in the decision-making process of transport users. Apart from the impact of air pollutants and GHG, which have been tackled over the years by policies and regulations at the EU and international level, other costs, such as congestion, accidents or noise costs, collectively known as external costs of transportation, are only now starting to be addressed. Intense research in the EU has allowed for the development of a comprehensive handbook for the calculation of these external costs [16]. On the other hand, transport demand is set to triple in the next 30 years [17]. This increase in transport volume will also result in an increase in congestion costs by about 50% in 2050, as well as an increase in the costs of accidents and noise [18]. SSS has here a significant advantage, as its average external costs per cargo unit and km are lower than those of other modes of transportation and, in particular, those of road transport, making the modal shift from to sea more appealing [19].

Finally, it should be mentioned that SSS may be beneficial in terms of fostering the development of countries outside of the developed world but still located in its immediate periphery, thus positively contributing to a number of the United Nations sustainable development goals [20], namely 1, 8, 10, 12 and 13, basically covering sustainable and balanced economic development aspects. These positive contributions are obtained in comparison with deep-sea shipping and land modes of transportation (particularly road), but it must be recognized that SSS will still have some negative impact on sustainable development goal 14 (impacts on oceans, seas, and marine resources). Nevertheless, the trade-off appears to be clearly positive for SSS.

2. Autonomous Navigation

SSS has been previously recognized for its dependence on manual procedures and traditional shipping techniques, and this industry has been the target of increasingly stringent environmental regulations, enforced by regional and global authorities such as the EU and the IMO [21]. Autonomous navigation, intelligent technologies, and digital solutions that aim to improve productivity, lower costs, and tackle environmental issues are surely able to assist SSS in entering a new era.

Firstly, the use of autonomous technologies can result in cost savings for SSS operators [22]. According to [23], automation concepts for SSS have encompassed both automated and traditional approaches utilizing ships and crewed vehicles. But over the past years, there has been a significant advancement in vehicle technologies, especially in the areas of electrical propulsion and automation, which can range from basic features like cruise control to more sophisticated ones like automated parking. When combined, these automotive technologies could enable automation in SSS. Examples of autonomous technology in SSS are autonomous vessels which can be used to navigate short sea routes without human intervention, relying on sophisticated sensors, radars, and artificial intelligence for safe and efficient transportation. Ships equipped with these technologies may lead to potential labour cost reductions along with safety improvements, especially since 75–96% of accidents on ships are caused by human error, with the higher values in this range applicable to busy shipping areas where most SSS occurs mainly due to limited crew rest time [24]. Additional technologies include automated port operation with automated cranes and other handling equipment, including also automated mooring, which increases the efficiency of SSS by reducing turnaround times, optimizing storage space, and lowering the risk of accidents. All these technologies are especially important for SSS ships, as they undertake short voyages in busy sea lanes with frequent but short port calls.

Given the fast development in the field of autonomous vessels, regulatory organizations are working to develop policies for approving autonomous ships [25]. The IMO issued MSC.1/Circ.1638 [26], containing the main results of a regulatory scoping exercise for the use of maritime autonomous surface ships (MASS). This document defines different degrees of autonomy from 1 to 4, with these degrees varying with the level of human action. In addition, several conventions such as SOLAS, COLREG, and others were reviewed. This exercise identified whether MASS could be regulated by any existing or future statutory instrument. To this purpose, a number of high-priority issues were identified, ranging from the need to develop MASS terminology and definitions, such as MASS, “master”, “crew” or “responsible person”, or the necessity to address the functional and operational requirements of the remote control station/centre and the possible designation of a remote operator as a seafarer. The need to analyse provisions regarding safety requirements that were previously under human control was also identified. For this purpose, the IMO suggested that the way forward may be the development of a goal-based MASS instrument.

One important topic when it comes to autonomous vessels in SSS is their comparison to autonomous vehicles performing land transportation. When analysing the paragraphs above, it is possible to identify some advantages and disadvantages of automation in SSS. Benefits of implementing automation in SSS include safety improvements by reducing the risk of human errors, which are the main cause for accidents in shipping; lower labour costs; and increased efficiency in SSS operation. Drawbacks and obstacles to the introduction of automation in SSS are the substantial initial investment since most of the technology is still being developed, job displacement, and existing regulatory challenges. When considering autonomous vehicles for land transportation some of their advantages are their user experience, efficiency, safety, mobility, productivity, energy, environment, and economy [27], along with the fact that land transportation remains faster than maritime transportation. Disadvantages to the automation in land transportation are similar to the ones for SSS and consist of the high cost of the initial investment, the lack of flexibility since it is only programmed to perform certain tasks, and legal and regulatory challenges [28][29]. Serious safety concerns arise due to the higher speed of land transportation and more intense traffic in roads, as compared to marine traffic.

When comparing automated transportation in SSS with automated transportation in land transport, it can be seen that they face similar challenges, particularly in the regulatory aspect of their implementation. Although land and sea transport are usually considered as competitors, the introduction of automation in both modes of transport will lead to an increase in the efficiency of operations and will particularly benefit intermodal transportation since it uses both modes, allowing for improvements when it comes to coordinating the different legs of the operation.

3. Autonomous Ship Concepts for Short Sea Shipping

The world's first autonomous, zero-emission container vessel, *Yara Birkeland*, went into commercial service in the spring of 2022. The zero-emission ship will carry mineral fertilizer to the regional export port in Brevik from Yara's production facility in Porsgrunn, Norway [30]. It was supposed to gradually transition towards full autonomous sailing during the first to years of operation; however, the duration of the transition increased to two years due to regulations [31]. KONGSBERG, which was responsible for the development and delivery of all essential technologies, also mention that unmanned operations were estimated to begin in 2024. This transition will occur by training an algorithm through data collection from the voyages and, eventually, radars, sensors, and artificial intelligence cameras will help the vessel navigate by itself. Nowadays, its automated capabilities consist of auto-docking, automated mooring, and other technologies [32]. Other autonomous vessels have commenced operations such as *ZhiFei*, a container vessel in China which began testing in October 2021 and will have the ability to be either fully autonomous, remotely controlled, or to have crew on board; some research vessels and military vessels in the US; and navy vessels in the United Kingdom have also been developed. In addition, there are also new projects being developed, such as two inland container vessels in Belgium and Netherlands or a domestic autonomous container vessel in Japan [33].

The primary reason for the lack of autonomous ship building projects [34] is the immature technology and regulations, along with the low amount of reliable evidence to support the benefits of implementing autonomous technologies into shipping. To solve this problem, Key Performance Indicators (KPIs) were developed in order to allow for this assessment, and this type of work is critical to facilitate other research regarding the feasibility of introducing these technologies into SSS.

One important aspect when it comes to the implementation of automation in SSS is the economic feasibility of the investment. According to findings in [35], it is concluded that there are insufficiently accurate financial models for autonomous shipping, and that the cost estimates are highly uncertain, particularly when it comes to insurance, cyber security, and contingency operations cost, leaving only a trustworthy assessment of particular case studies.

A case study focused on an autonomous container ship for short sea trades is presented in [36], with the main objective of evaluating the economic feasibility of such a ship. In this scenario, a conventional ship and an equivalent autonomous ship under the same technic and commercial conditions are compared, with the objective of understanding how much higher the new building price and costs of the remote operations centre may be to deliver the same internal rate of return. The conclusions were that an autonomous ship could cost up to 32% more while still ensuring the same internal rate of return.

A study in [37] examines the conversion of a cargo ship used in SSS in Norwegian waters into an autonomous ship, along with the design of the crewless ships of the future. It was concluded that when compared to other shipping types, such as ocean-going vessels, MASS adoption on SSS routes with frequent port calls is anticipated to show a larger economic margin for the operators. The impact of fleet configuration is analysed [38] on the cost of liner shipping operations by examining a model in a data instance that converts conventional to autonomous vessels in a case study on the Baltic trade. The results show that the implementation of autonomous vessels brings savings when compared to traditional vessels and, in addition, the results also imply that because of its improved capacity to adapt to the asymmetry of trade, a fleet configuration that combines large and small vessels performs better, which seems to be a common configuration applied in operations when considering autonomous vessels.

An analysis of the financial ramifications of employing autonomous vessels instead of conventional ones within the future of vessels is presented in [39]. In order to achieve this, a SSS network for the shipping of containers between ports in Europe and Norway's coastline was designed using a mother and daughter route concept. Comprehensive computational trials that took into account the different existing problems led to the conclusion that the introduction of autonomous daughter vessels decreased the operational costs in addition to delivering lower fuel consumption, which benefited the environment. When also turning the mother vessel into an autonomous ship, the benefits were even greater.

4. Research Projects in Automation for Short Sea Shipping

While the funding specifically assigned by the European Union to promote research in SSS has decreased significantly in recent years, also in line with there being less funding dedicated to promoting SSS, there are a couple of recent research projects under the EU's Horizon 2020 research and innovation program that deal with the automation and digitalization in SSS. The AEGIS project [40] was a three-year endeavour which started in June 2020 and ended in November 2023, with a total funding of EUR 7.5 M from the EU's Horizon 2020 research and innovation program. It was dedicated to developing a brand-new, environmentally friendly, dependable, adaptable, automated, and autonomous waterborne transportation system for Europe that can link both rural and urban terminals [41]. The AEGIS consortium worked to develop a new, disruptive SSS feeder-loop service based on mother and daughter ships [42]. Additionally, this project leveraged cutting-edge advancements in connected and automated transport, incorporating smaller and more adaptable vessel types, automated cargo handling, autonomous ships, standardized cargo units, and new digital technologies. A number of different user cases were developed in this project. One of them refers to a maritime transport corridor from the west coast of Norway down to the continent, for which a container vessel with 1000 TEU capacity was designed [43]. It will operate with a low autonomy level, carrying crew on board, but including automated mooring and automated cargo handling. Other vessels projects are a coastal feeder service vessel, a push boat, a barge convoy, and a self-propelled shuttle, with the latter three designed to, one day, become fully autonomous vessels while being monitored in a control centre.

Another project is called MOSES, which began in July 2020 and ended in December of 2023 [44]. This project aimed to bolster the SSS component within European supply chains. It involved addressing vulnerabilities and challenges associated with the operation of large containerships and its consequences in the feeder segment of SSS. The strategy involved a dual approach: reducing the total time to berth for TEN-T hub ports and promoting the utilization of SSS feeder services to smaller ports with limited or no infrastructure. The three main innovations developed within the MOSES project are MOSES innovative feeder vessel, followed by the MOSES AutoDock system, which is an autonomous vessel manoeuvring and docking scheme, and the MOSES Platform, which is a digital collaboration and matchmaking platform specifically designed for SSS traffic. The MOSES innovative feeder vessel equipped with a robotic container-handling system [45] will be aimed at streamlining the (un)loading processes of containerized cargo at hub ports. This innovative system not only enhances the efficiency of cargo operations at major ports but also contributes to the increased operational capacity of smaller ports.

The goal of the MOSES AutoDock system is to automate big container ships' manoeuvring and docking at deep-sea shipping ports, seeking to cut the time it takes for container ships to dock and manoeuvre in large terminals by 20% in order to lower the cost of ship handling at the port [46]. Additionally, the risks and injuries brought on by conventional line mooring techniques and manoeuvring accidents may be eliminated or significantly reduced. The MOSES Platform seeks to maximize the efficiency of SSS services by using data-driven analytics to match demand and supply. Several shippers' information will be combined by the platform, which will then make the information available to logistics service providers. It will support scenario-building capabilities and allow for varying degrees of user interaction based on the needs of the stakeholders. Additionally, it will include a dedicated module for exchanging information about empty containers. Lastly, shippers and carriers will be able to combine flows for both directions on the MOSES digital match-making platform, which will be backed by appropriate governance models, handle planned deliveries, and spot capacity [47]. The advantage of this platform for SSS when compared to the previously mentioned platforms is that it was especially designed for this type of shipping, making it even more efficient; in addition, it was developed within the scope of the EU, facilitating its application in the SSS market.

Finally, the Autonomous Shipping Initiative for European Waters (AUTOSHIP) started on July 2019 and will end in December 2024, and it aims at speeding-up the transition towards a next generation of autonomous ships in the EU [48]. The project will build and operate two distinct autonomous vessels with a focus on goods mobility in order to demonstrate their operational capabilities in scenarios involving inland waterways and SSS. The project's goals range from developing and deploying autonomous vessels to improving digital tools or devising ways to advance autonomous ships beyond the state of the art. Two different scenarios will be analysed in this project, one being an SSS fish feed carrier sailing between Skretting and Cargill and serving fish farms along the Norwegian coast. The other scenario is an inland waterways shuttle barge operating for the transportation of goods in large bags or on pallets in the Flemish region, which is centred around the important EU port of Antwerp. The project's two user cases will serve as a showcase for the full suite of technologies for autonomous operations. Along the vessel's route, functions and controls, including fully autonomous and remotely controlled sailing, will be determined.

In general, it can be seen from the user cases considered in the research projects described above that autonomous navigation is likely to mainly benefit applications typical of short sea shipping, namely those involving short freight transport routes or repetitive activities.

5. Impact of Autonomous Navigation in Short Sea Shipping

All in all, the impact of automation on SSS was assessed by analysing the existent and future technologies that could benefit SSS in the future. Autonomous navigation could be of advantage for SSS since it would reduce the labour costs along with increasing the safety of voyages. Autonomous technologies in SSS can consist of both of fully autonomous vessels, automation assisting a crewed vessel, and automated port operation with automated cranes and other handling equipment, including also automated mooring. All these technologies boost an operation's efficiency and can turn SSS into a more competitive alternative. The major constraints to introducing these technologies in SSS operations are, currently, costs and regulatory obstacles. Examples of existing autonomous vessels were then provided, and it was concluded that the lack of further autonomous ship projects is primarily due to a lack of confidence in novel technologies, lack of regulations, and absence of trustworthy data which can validate the advantages of integrating autonomous technologies into the shipping industry. Nonetheless, some casestudies demonstrate the existing potential for the use of autonomous navigation in SSS. A number of EU research projects, such as AEGIS, MOSES, and AUTOSHIP, are indeed focused on investigating and developing new autonomous technologies.

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